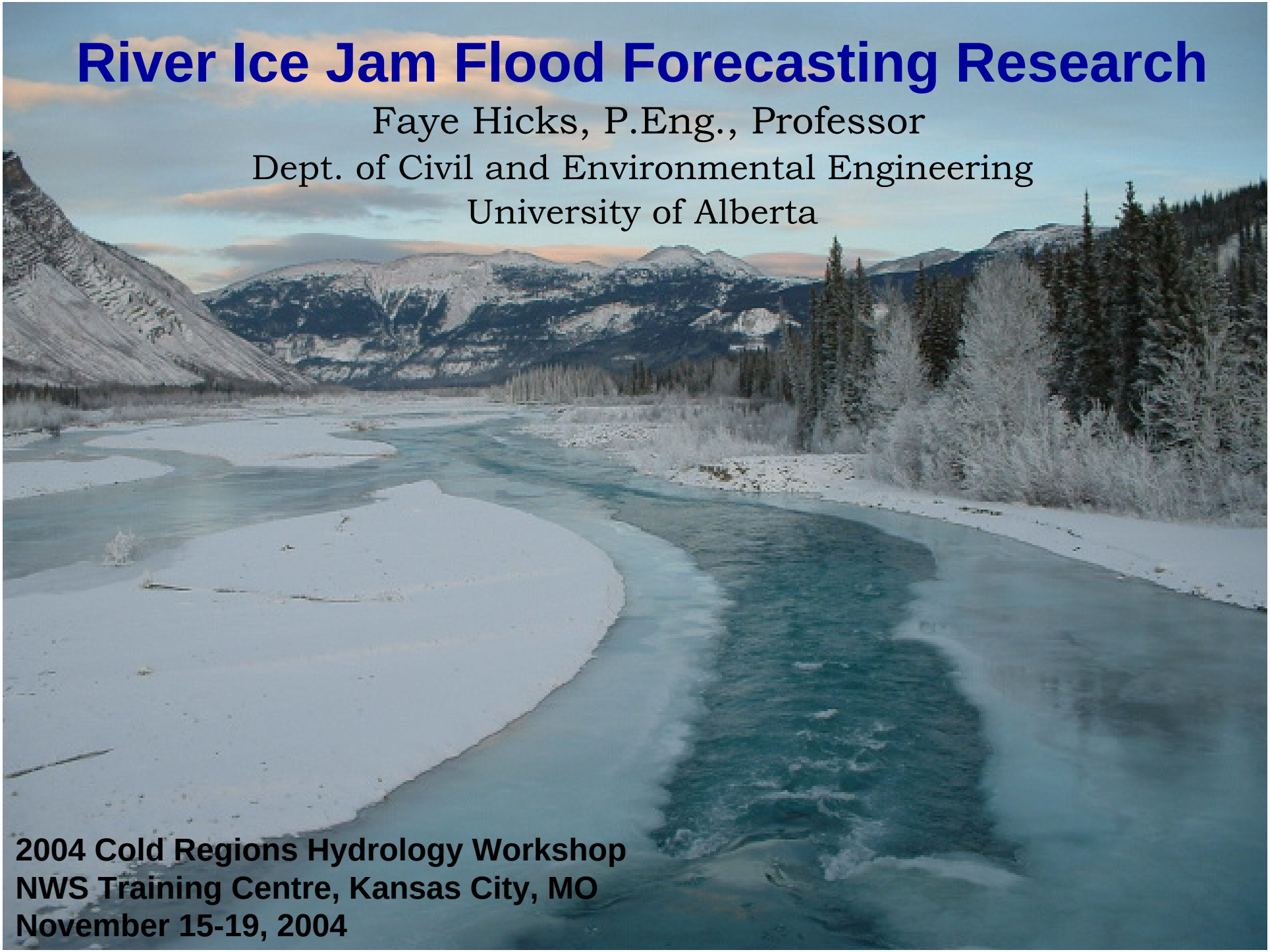
River Ice Jam Flood Forecasting Research

Faye Hicks, P.Eng., Professor
Dept. of Civil and Environmental Engineering
University of Alberta



2004 Cold Regions Hydrology Workshop
NWS Training Centre, Kansas City, MO
November 15-19, 2004


Beaufort Sea
Baffin Bay
Davis Strait
GREENLAND
(DEN.)
Nuuk
Fairbanks
ALASKA
Anchorage
Taloyoak
Iqaluit
Labrador Sea
NUNAVUT
YUKON TERRITORY
NORTHWEST TERRITORIES
Baker Lake
Hudson Strait
Gulf of Alaska
Juneau
Yellowknife
Rankin Inlet
Arviat
NFLD.
Happy Valley–Goose Bay
Hudson Bay
QUÉBEC
BRITISH COLUMBIA
ALBERTA
Edmonton
SASKATCHEWAN
MANITOBA
ONTARIO
Moncton
N.B.
ME.
Vancouver
Calgary
CANADA
Pacific Ocean
Seattle
Regina
Winnipeg
Thunder Bay
Montréal
Augusta
Portland
WASH.
MONTANA
N. DAK.
Duluth
Lake Superior
Ottawa
N.Y.
Boston
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MINN.
Bismarck
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Toronto
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OHIO
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San Francisco
NEVADA
UTAH
COLORADO
Kansas City
ILLINOIS
KY.
Virginia Beach
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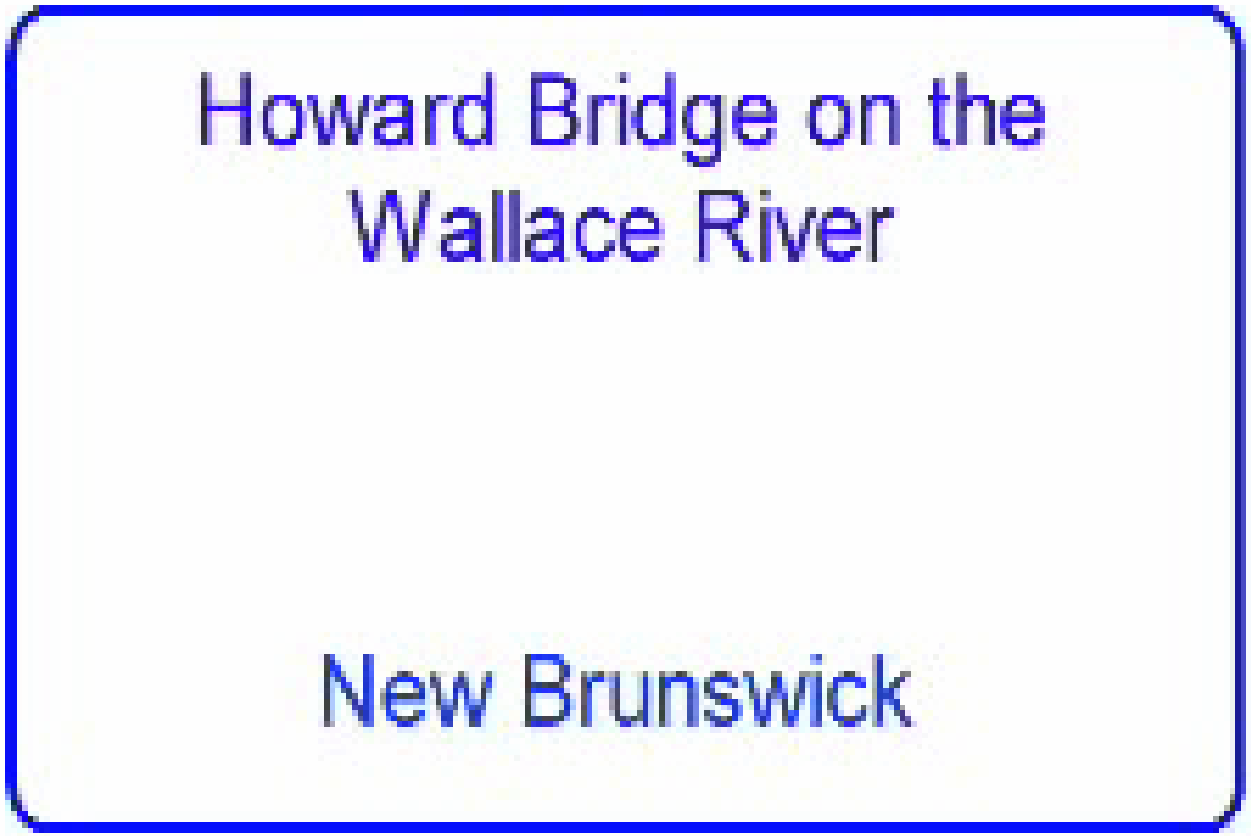
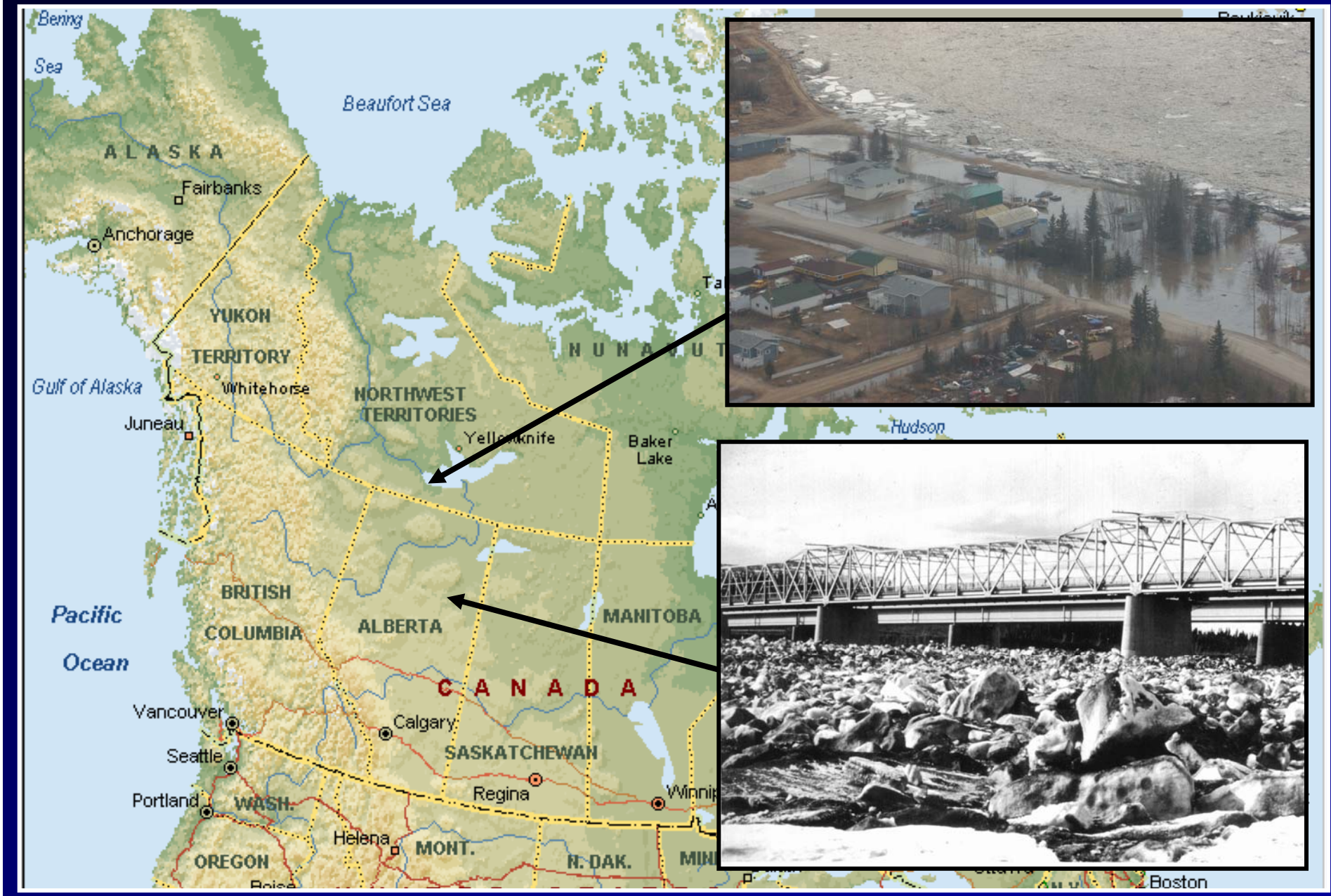
MO.
Charlotte
Las Vegas
Nashville
Wichita

Ice jams are a common problem in Canada


Howard Bridge on the
Wallace River
New Brunswick

Ice jams are a common problem in Canada



Ice Jam Issues in Alberta

1. Regulated rivers
    - restriction of hydro-peaking in winter
    - limits winter power production
    - balance made up using coal based power generation

2. Unregulated rivers
    - primarily break-up ice jams
    - north flowing rivers
    - risk to life and property

University of Alberta
River Ice Engineering Research

- Experimental Studies
  - ice jam formation (effects of hydro-peaking)
  - river ice floe hydrodynamics
- Field Studies
  - documenting ice jam formation and release
  - RADAR remote sensing for ice characterization
- Computational Model Development
  - RIVER1D and RIVER2D (public domain)
  - ice jam flood forecasting

for more information, please see www.riverice.ca

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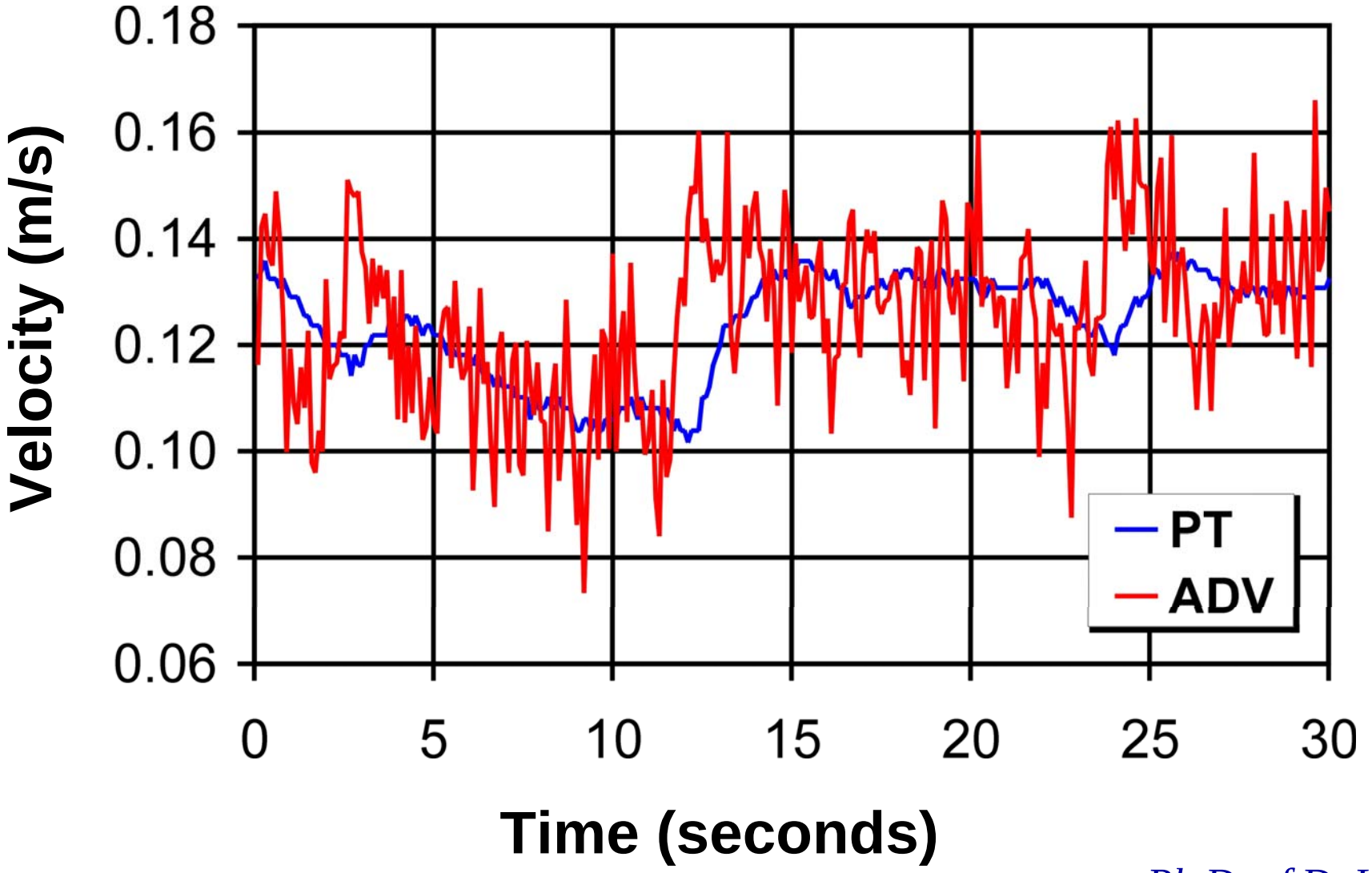
Ice Jam Formation


PLAY
1:32:38 PM

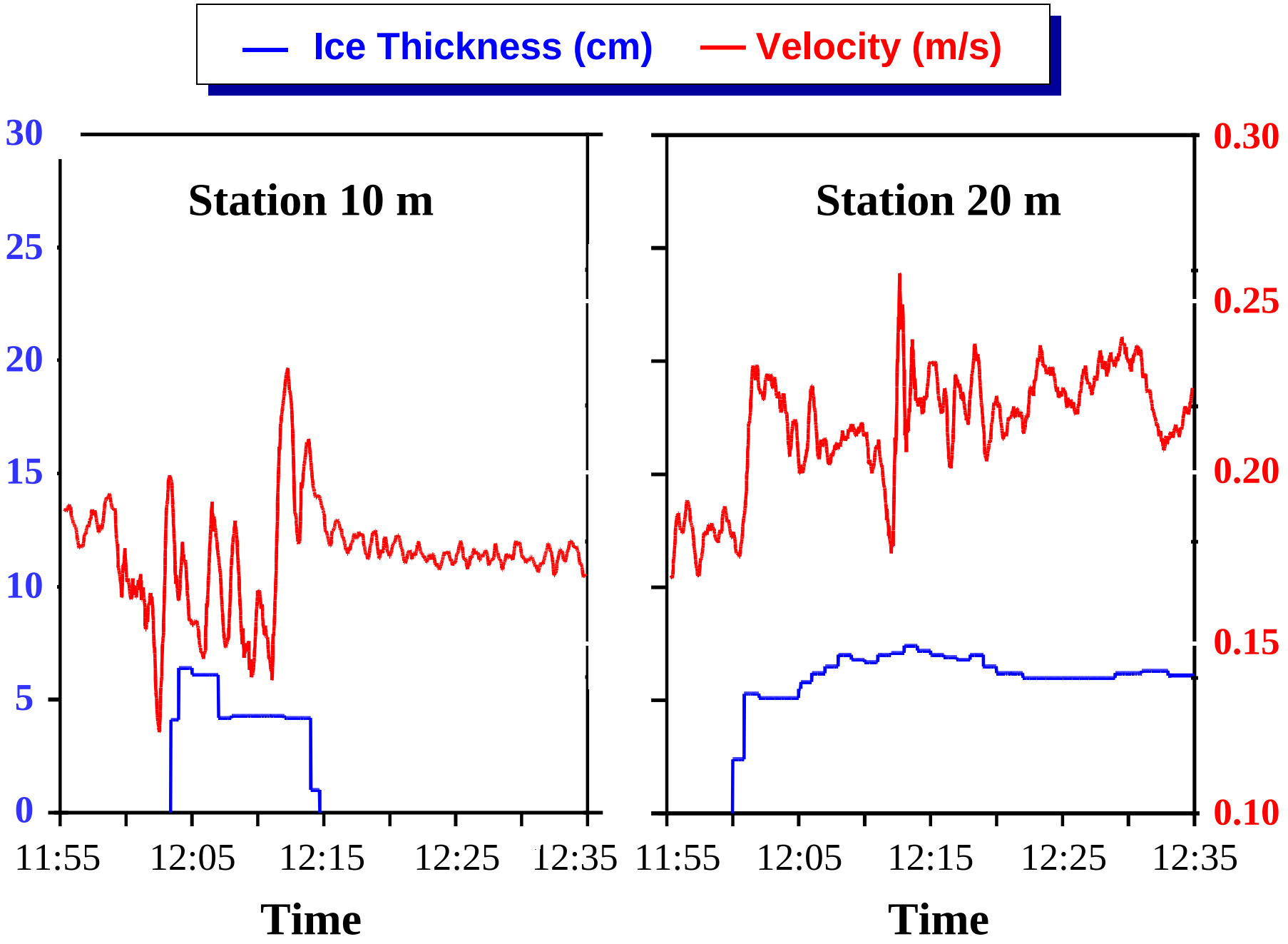

22
22.50
23
Station 23m

Comparison between **ADV** & **PT**

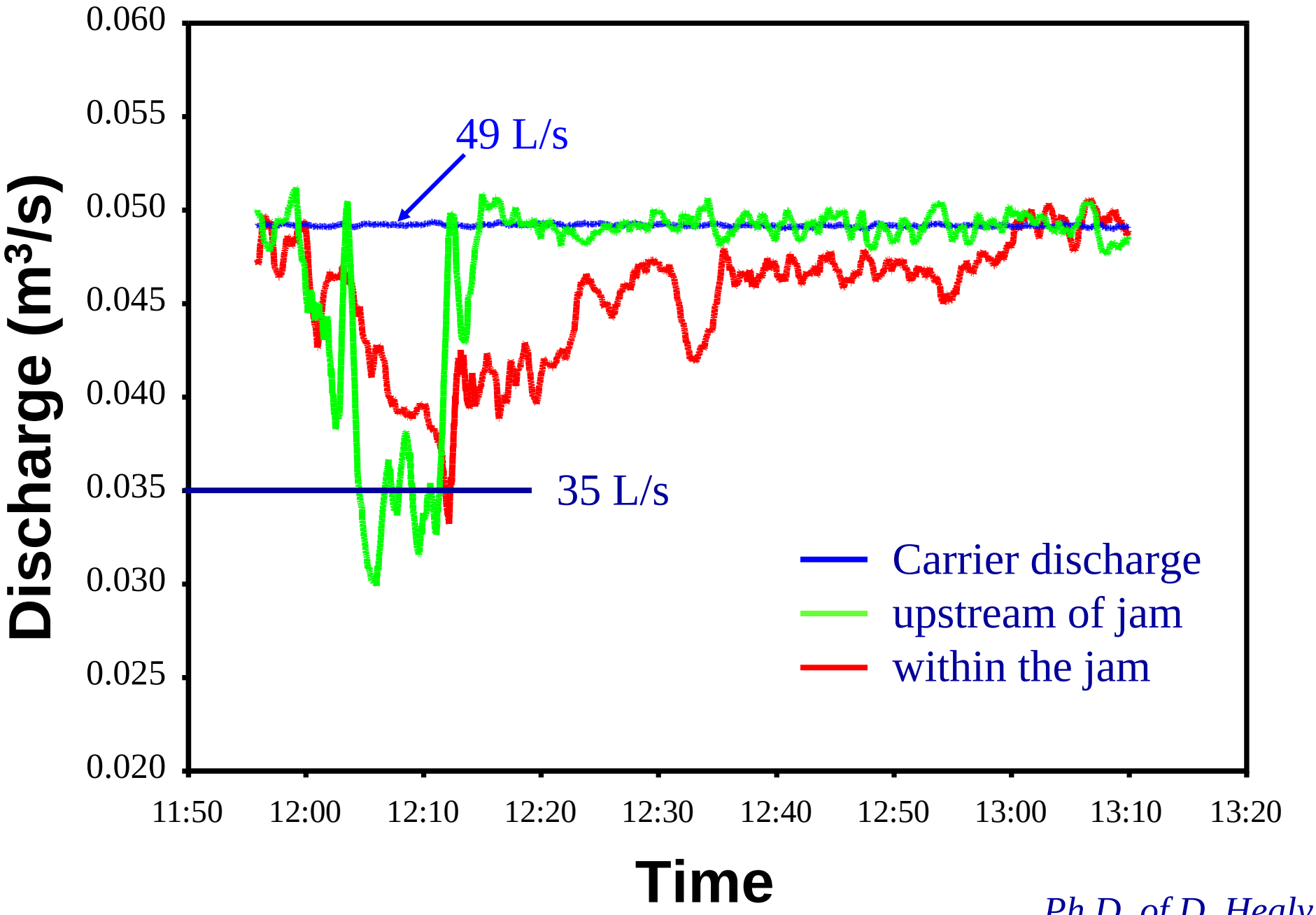


Ph.D. of D. Healy


PLAY



Ph.D. of D. Healy



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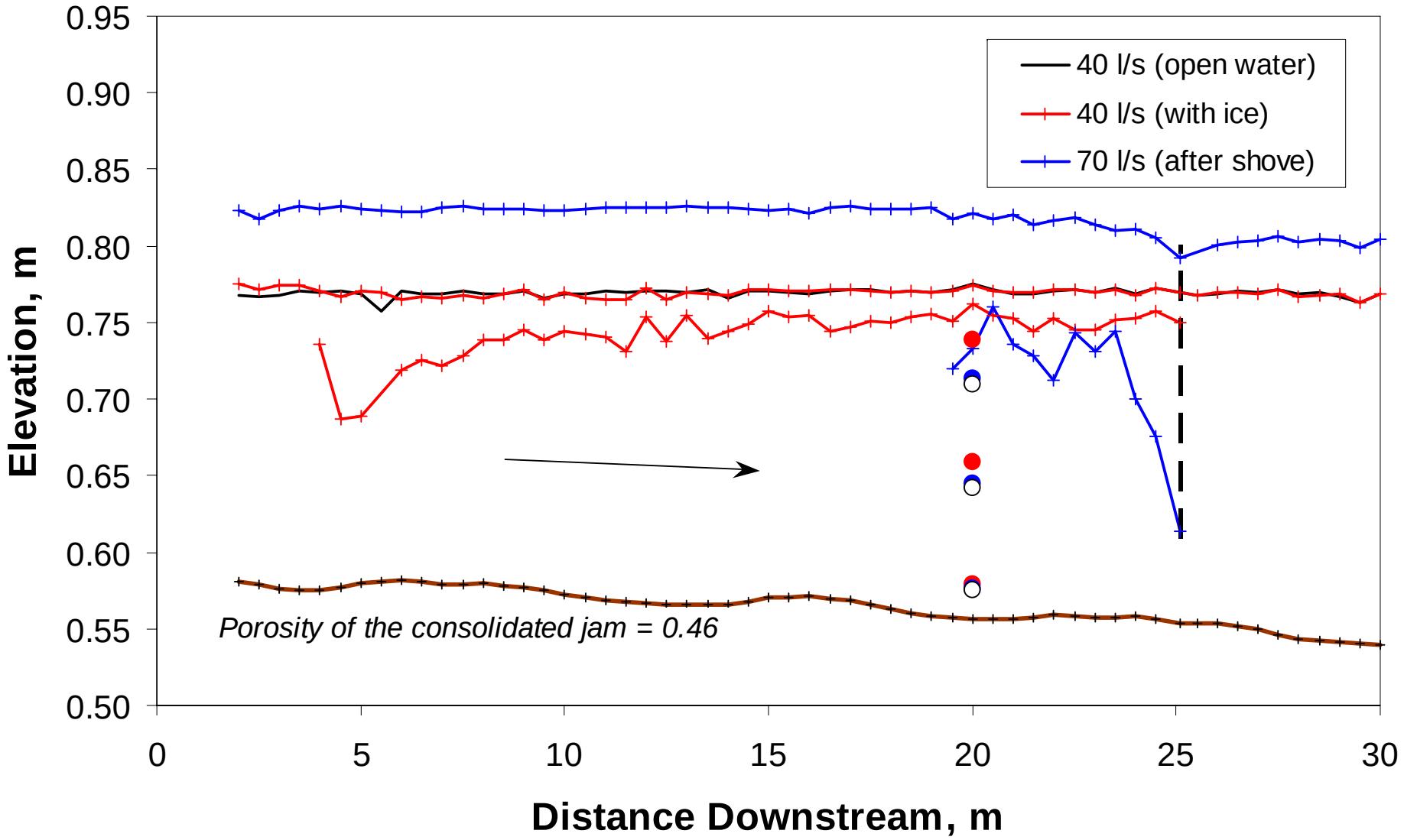
Profiles before and after consolidation



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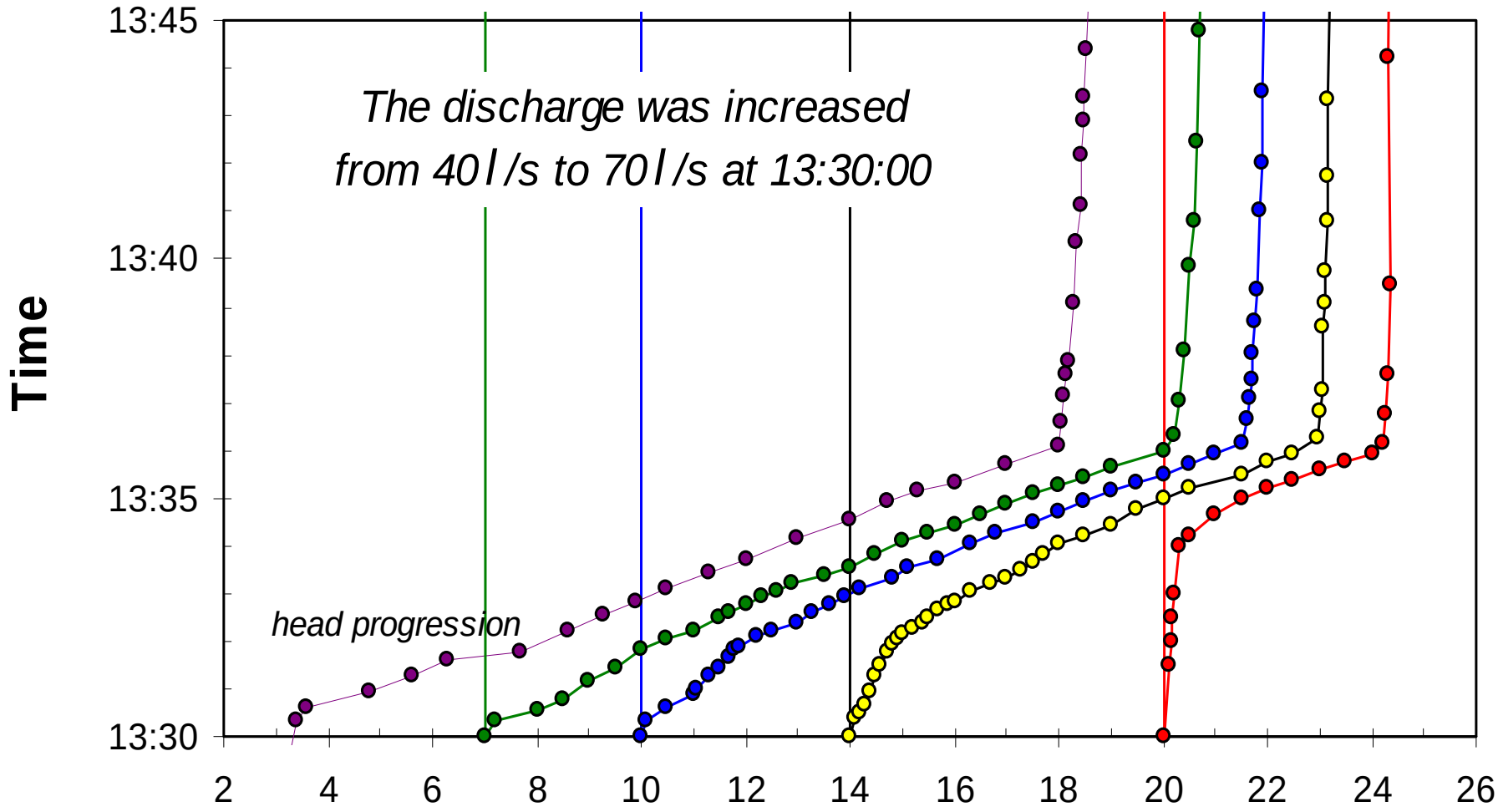
Tracking Particles

Propagation of head and tracking particles during consolidation



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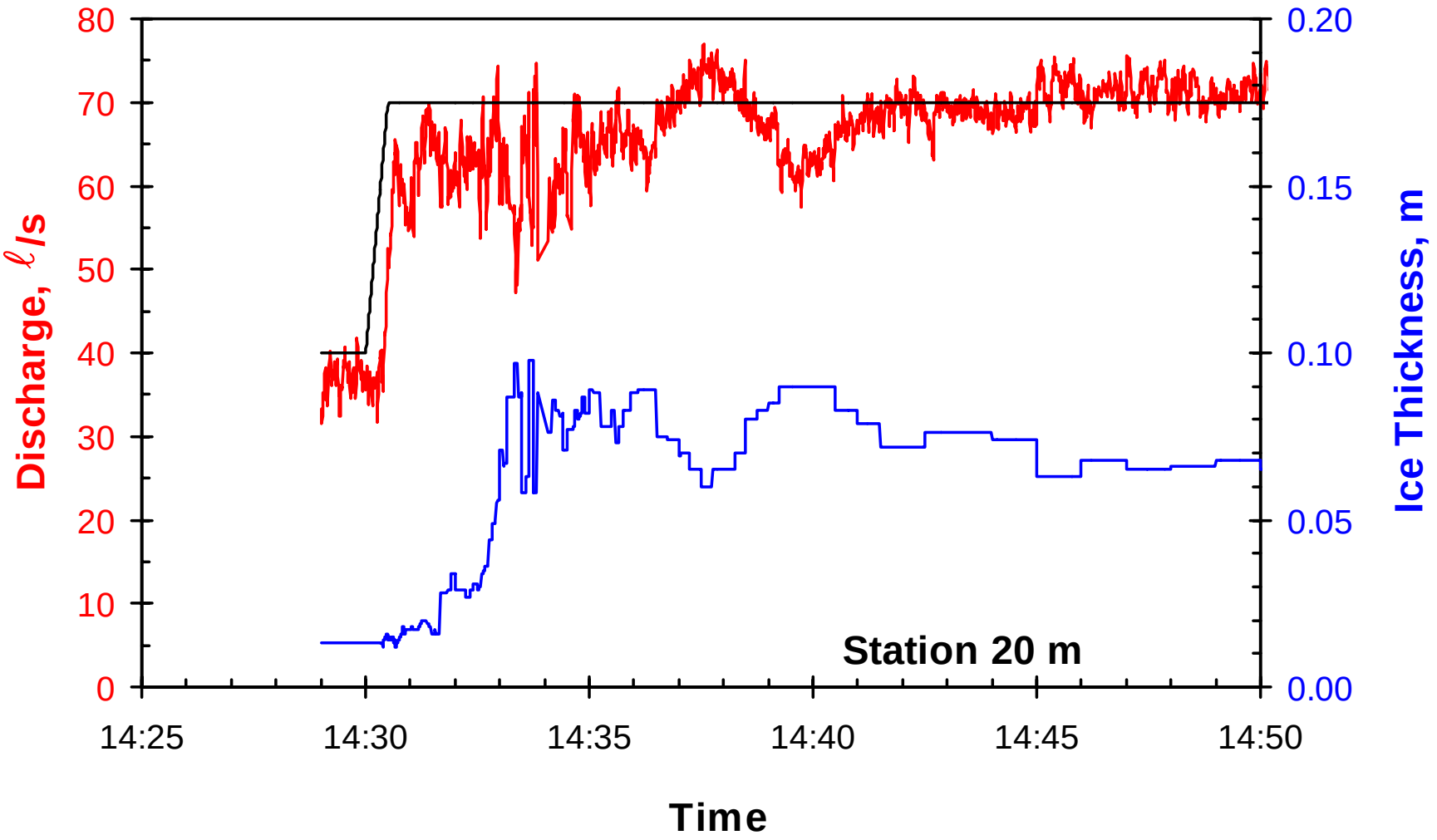
Discharge and ice thickness variation during consolidation



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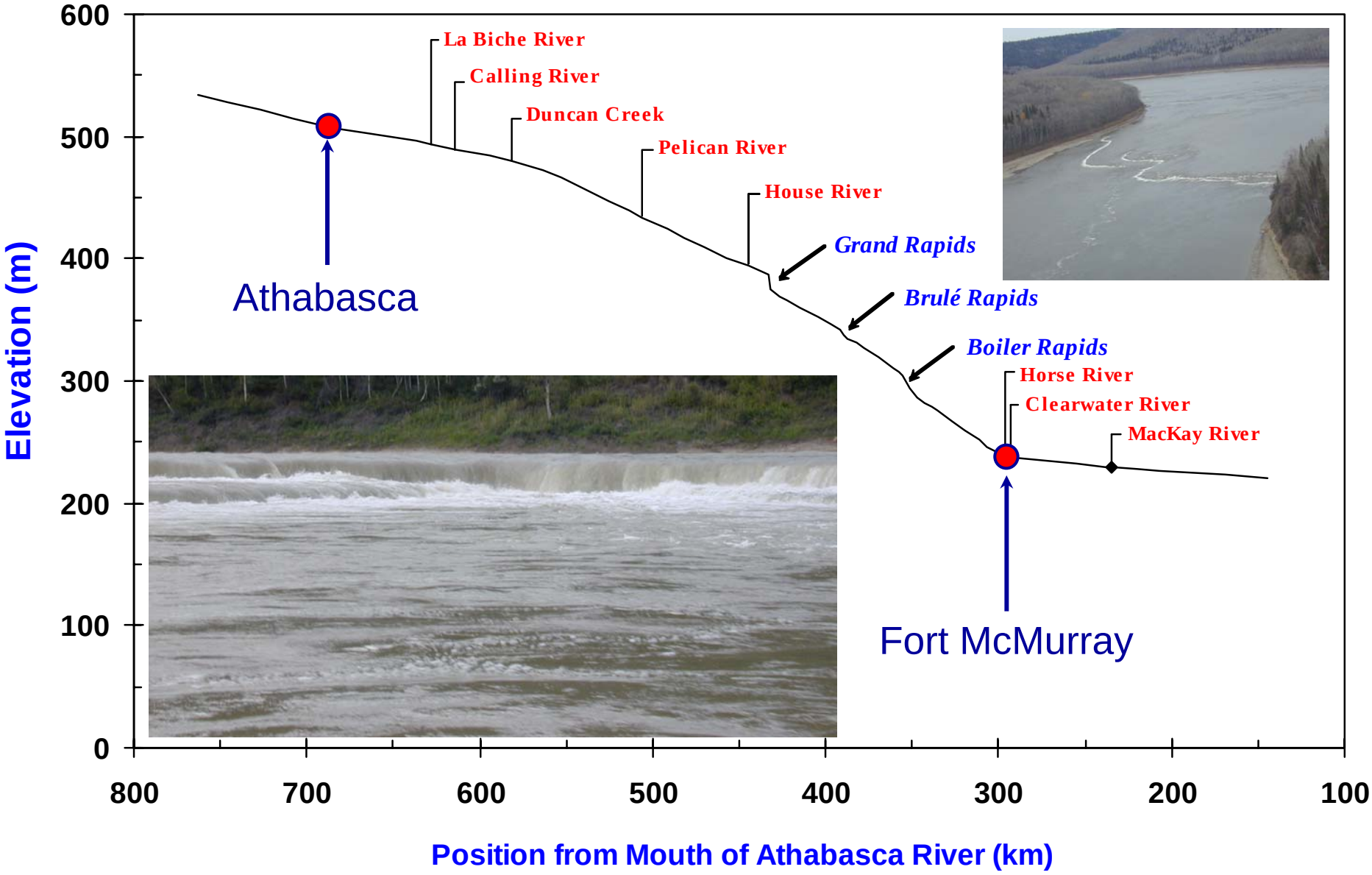
for more information, please see www.riverice.ca

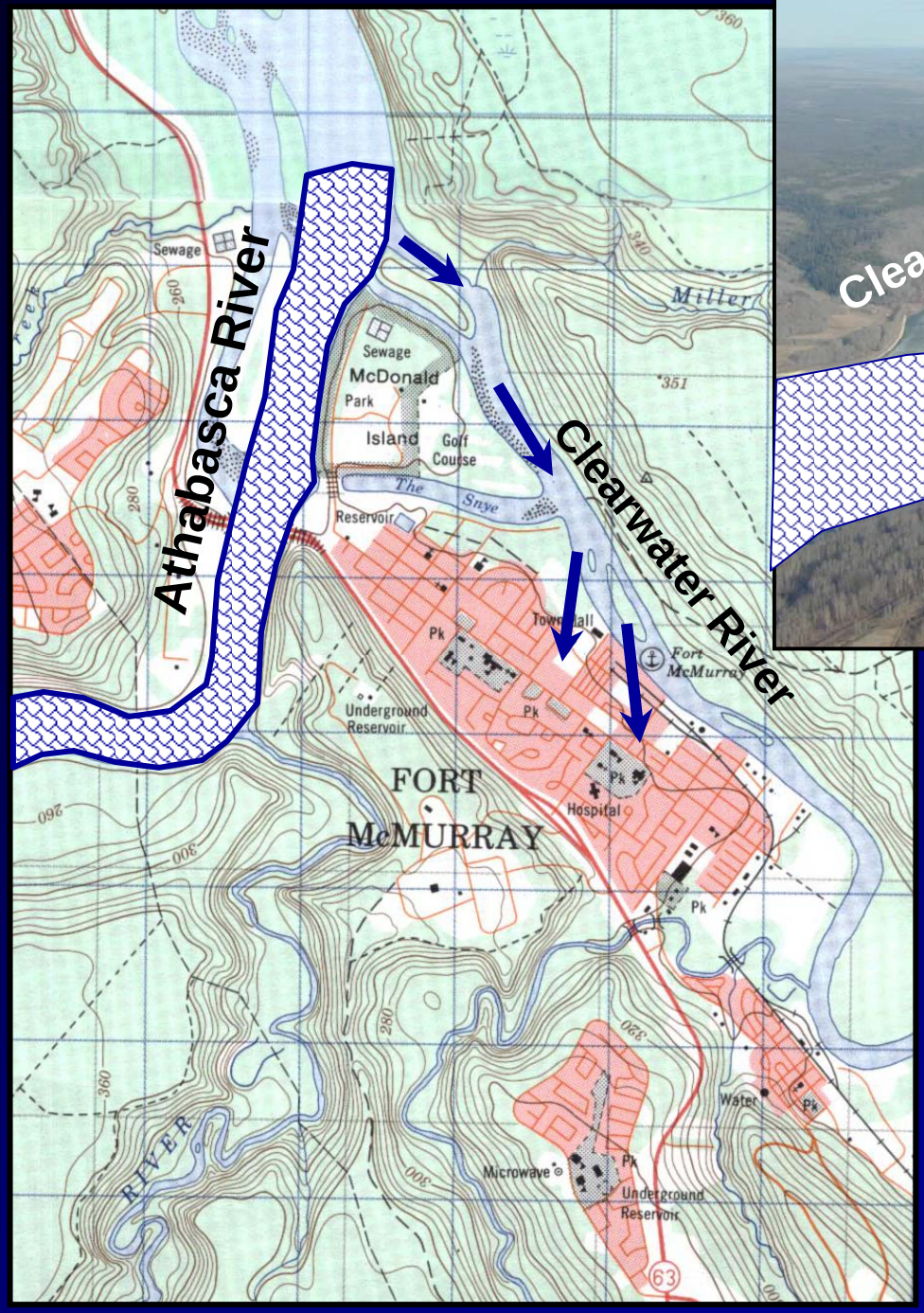
Our study site:

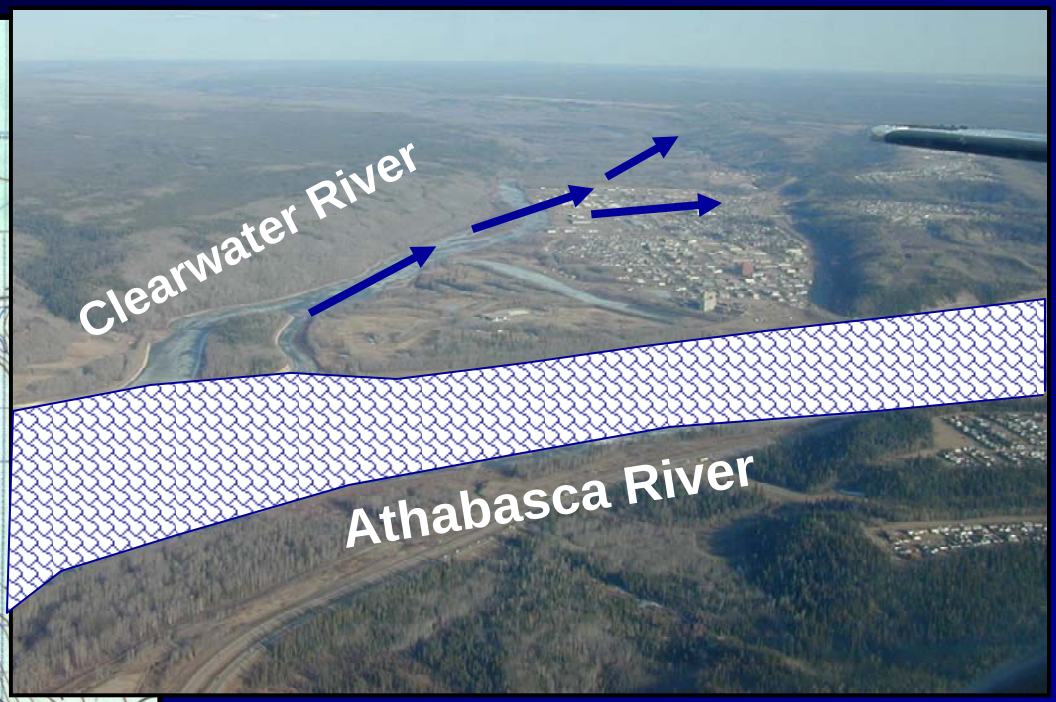
Athabasca River
at Fort McMurray, AB

- **Population ~40,000**
- **originally a fur trading post (~1875)**
- **major industry now: oil resource development (Alberta Oil Sands)**

Breakup is very dynamic in the steep reach upstream of Fort McMurray.







Flooding occurs when ice jams form on the Athabasca River downstream of the confluence with the Clearwater River.

Water backs up the Clearwater River and overtops the low banks, flooding the downtown area.

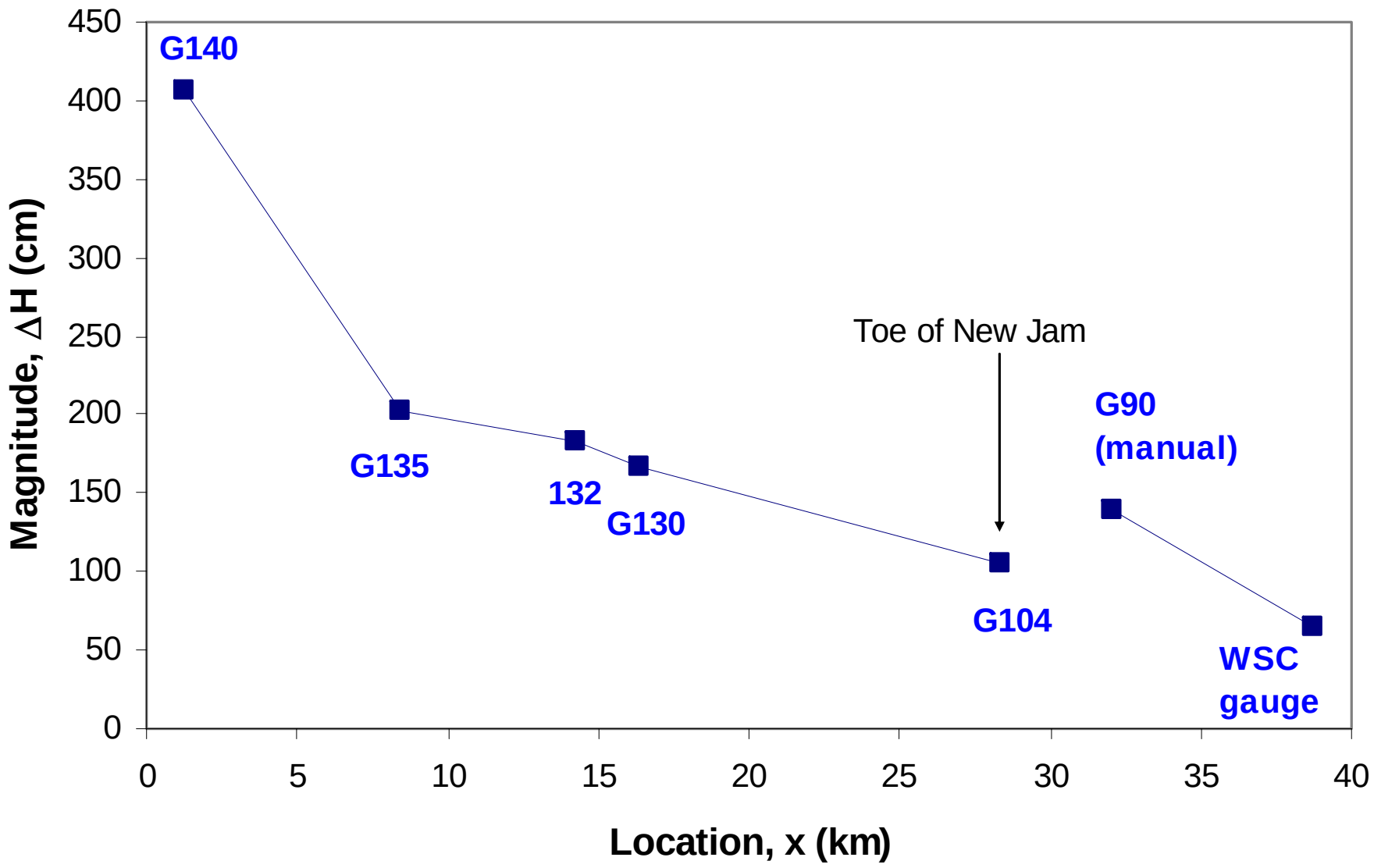
Remote monitoring stations have been installed upstream of Fort McMurray

(photo courtesy of Alberta Environment)

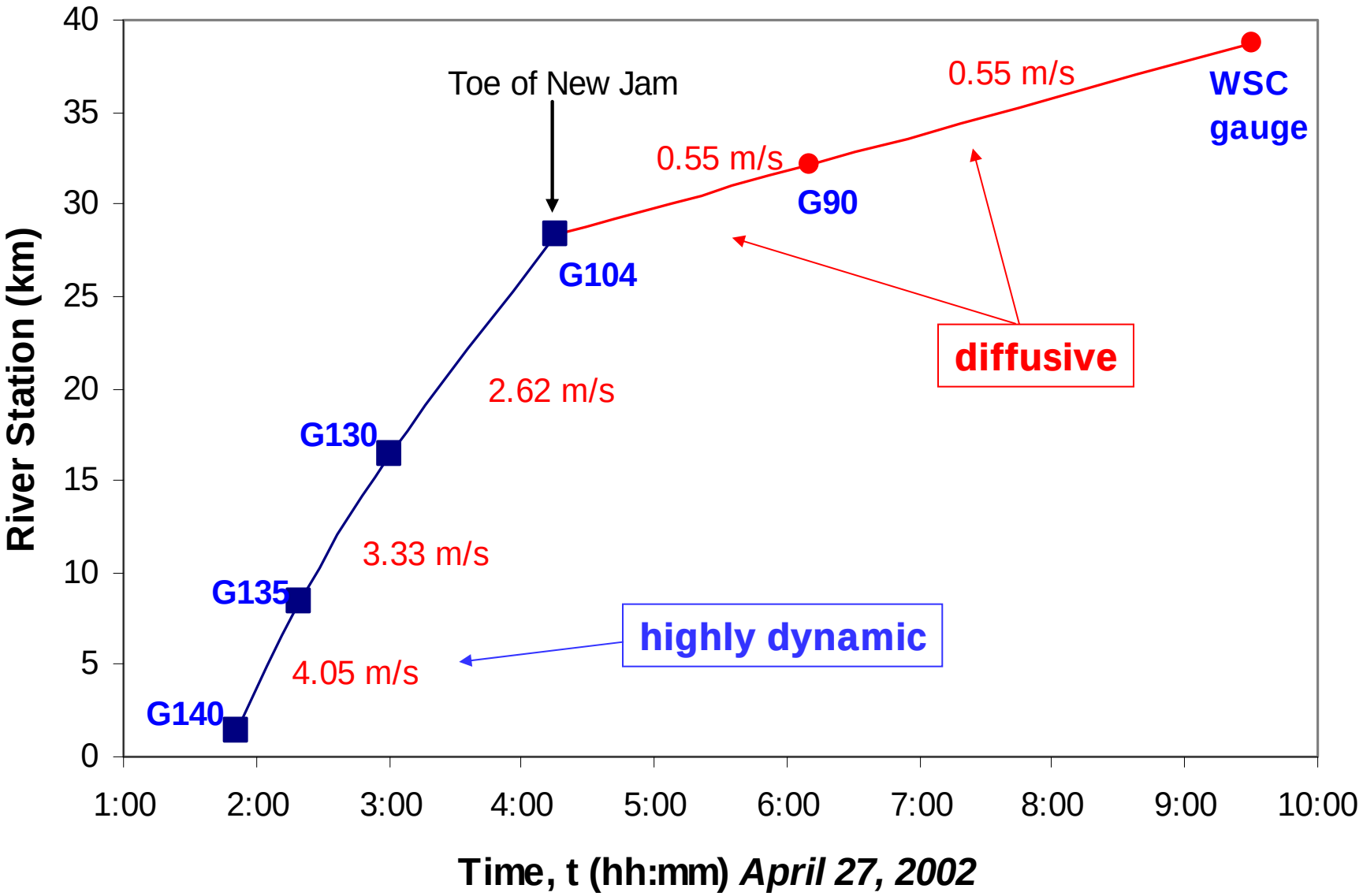
09:30
0.6m
G55
WSC Gauge
07DA001
G60
Sewage
Lagoons
06:10
G65
1.4m
G70/75
Clearwater
River
G85
G80
G90
G95
G100
Moberly
Rapids
FORT
McMURRAY
Little Fishery
River
Golf
Course
G110
G105
Horse
River
63
04:16
1.0m
G115
02:55
G120
G122
1.8m
G125
Mountain
Rapids
G130
Alger
Creek
03:00
1.7m
01:51
4.1m
G135
Cascade
Rapids
G150
Crooked
Rapids
G140
G145
Little
Cascade
Rapids
Rock
Rapids
02:20
2.0m

Surge wave measured during 2002 ice jam release event

Wave Peak Attenuation



Measured Wave Speeds



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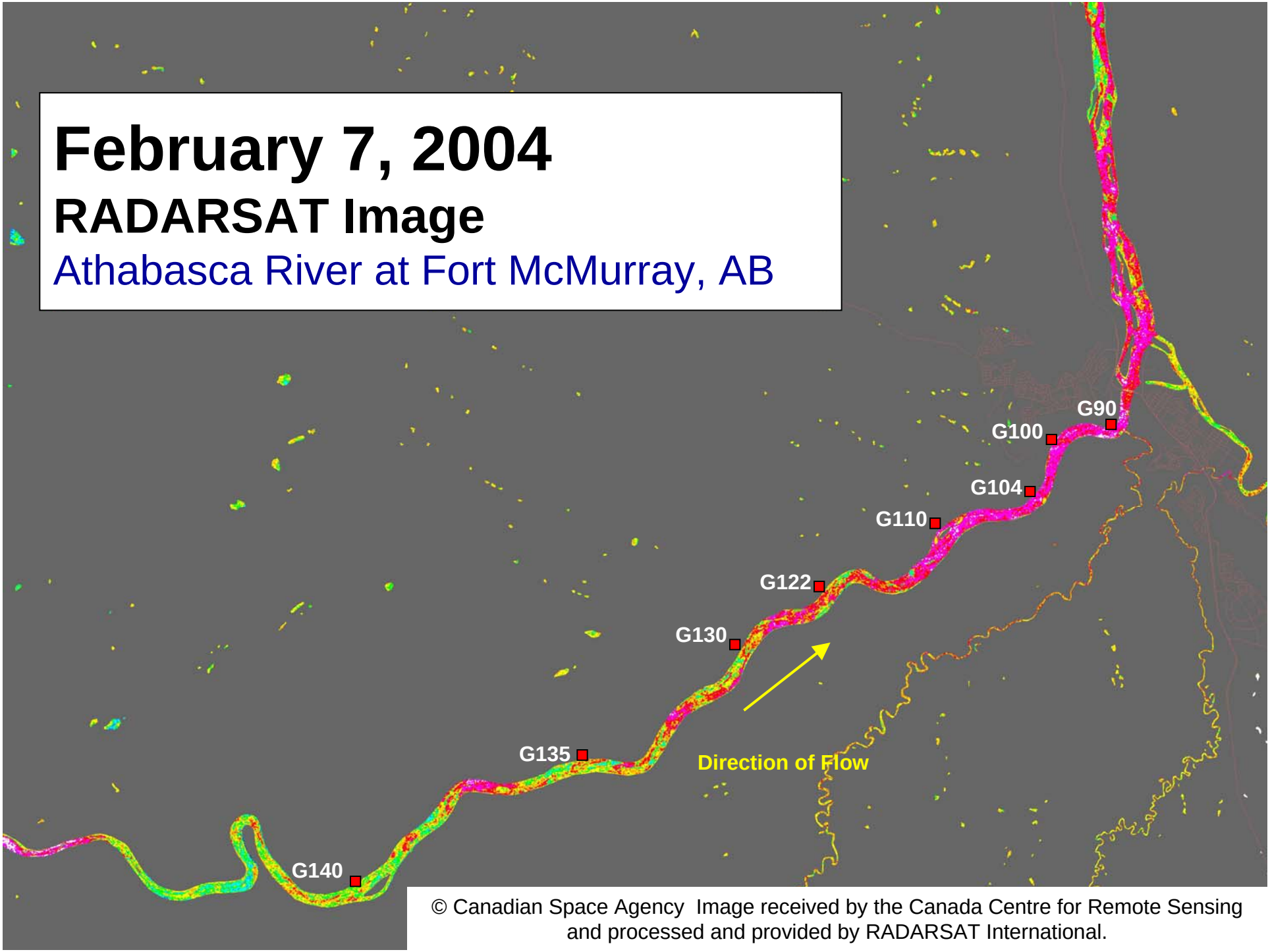
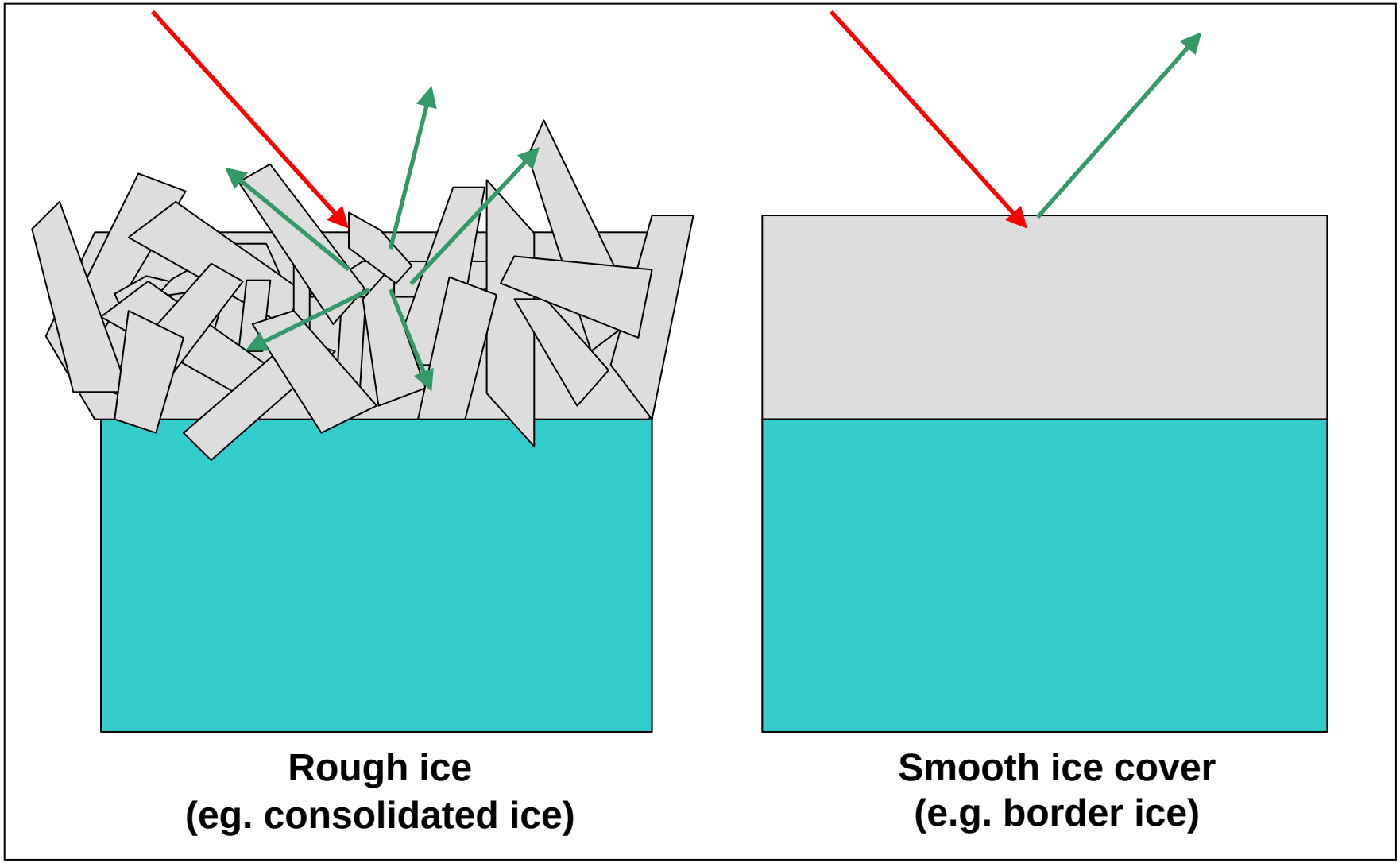
This project has been conducted in collaboration with
Dr. Joost van der Sanden at the
Canada Centre for Remote Sensing (CCRS)

RADARSAT-1

(http://www.space.gc.ca/asc/eng/default.asp)

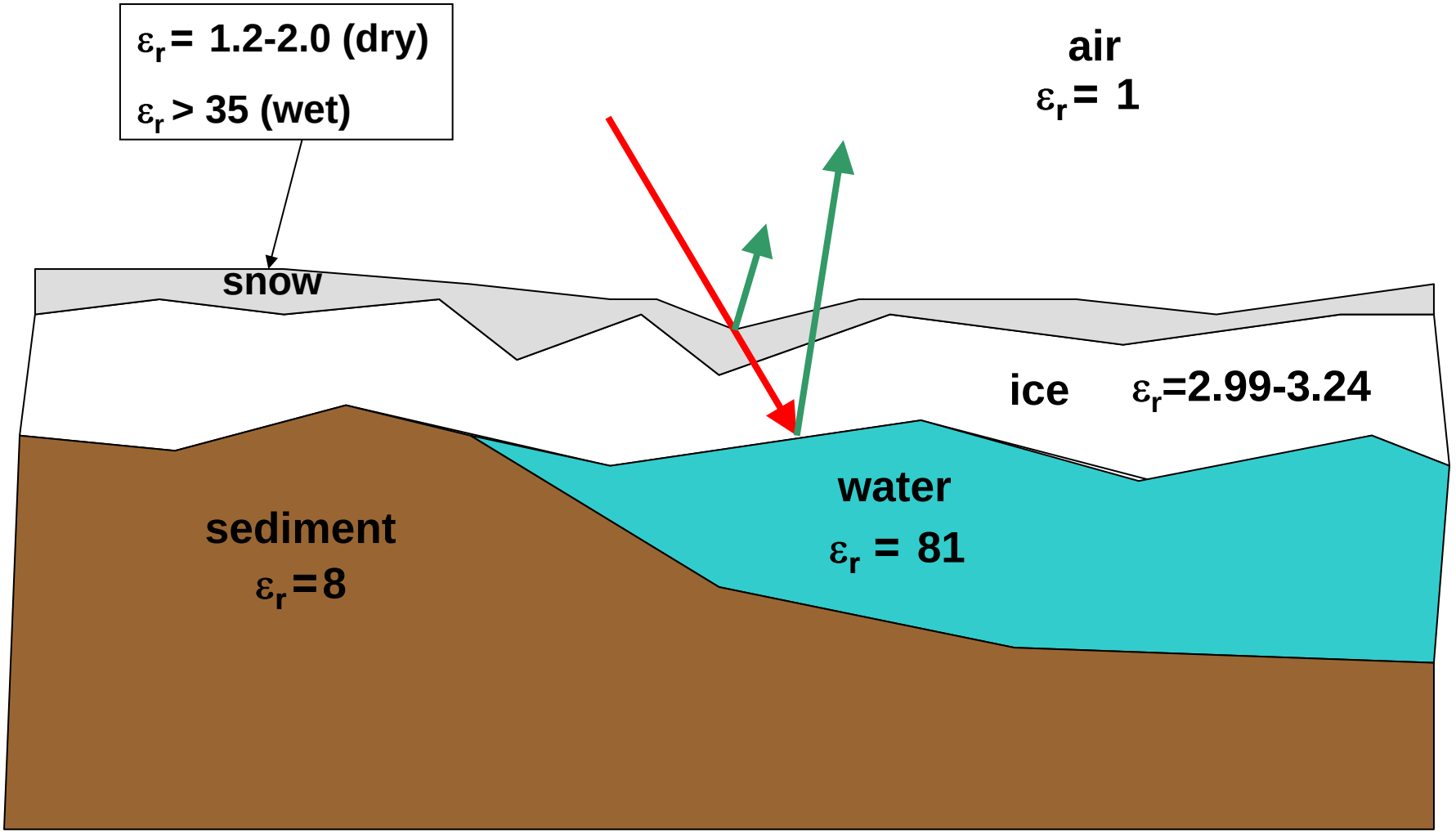


Ice texture at the scale of the wavelength affects surface scatter

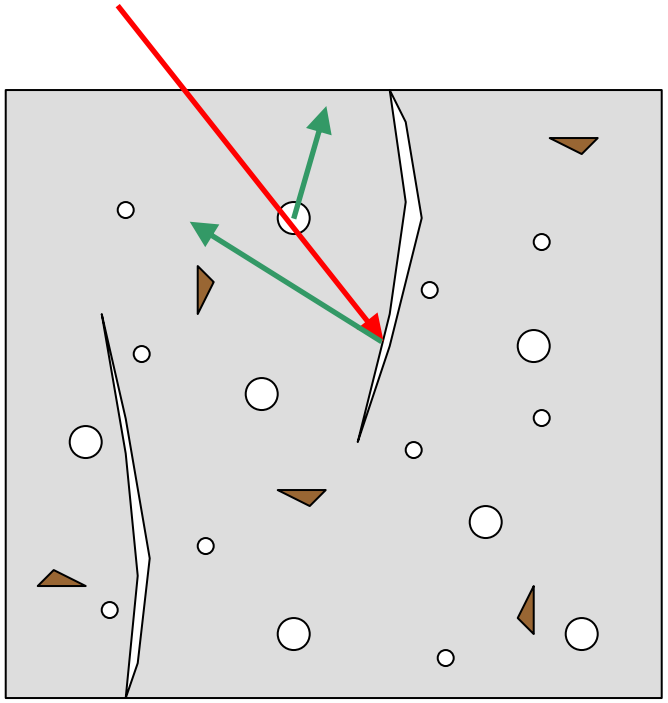


Dielectric Constant, ε_r

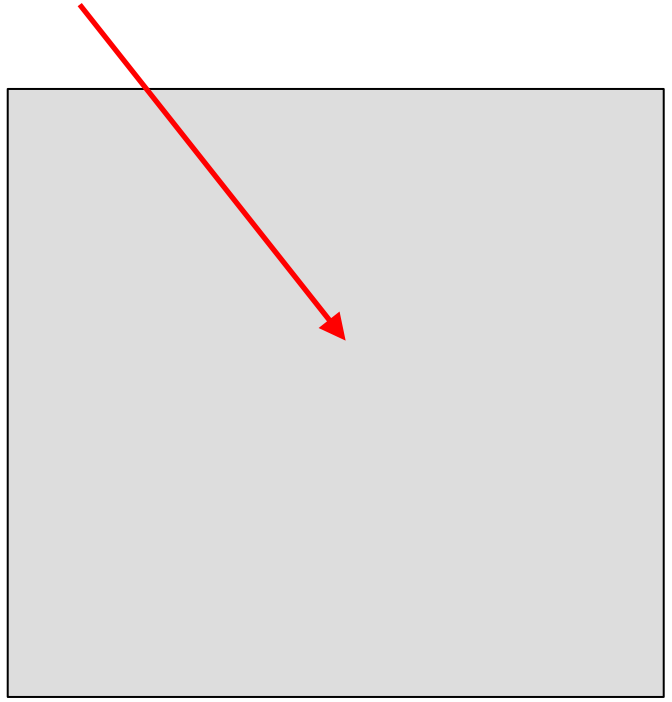
As ε_r increases, penetration depth is reduced, and reflectivity increases



Bubbles, impurities, and cracks cause dielectric discontinuities and increase volume scattering



Higher radar return due to volume scattering



Lower radar return

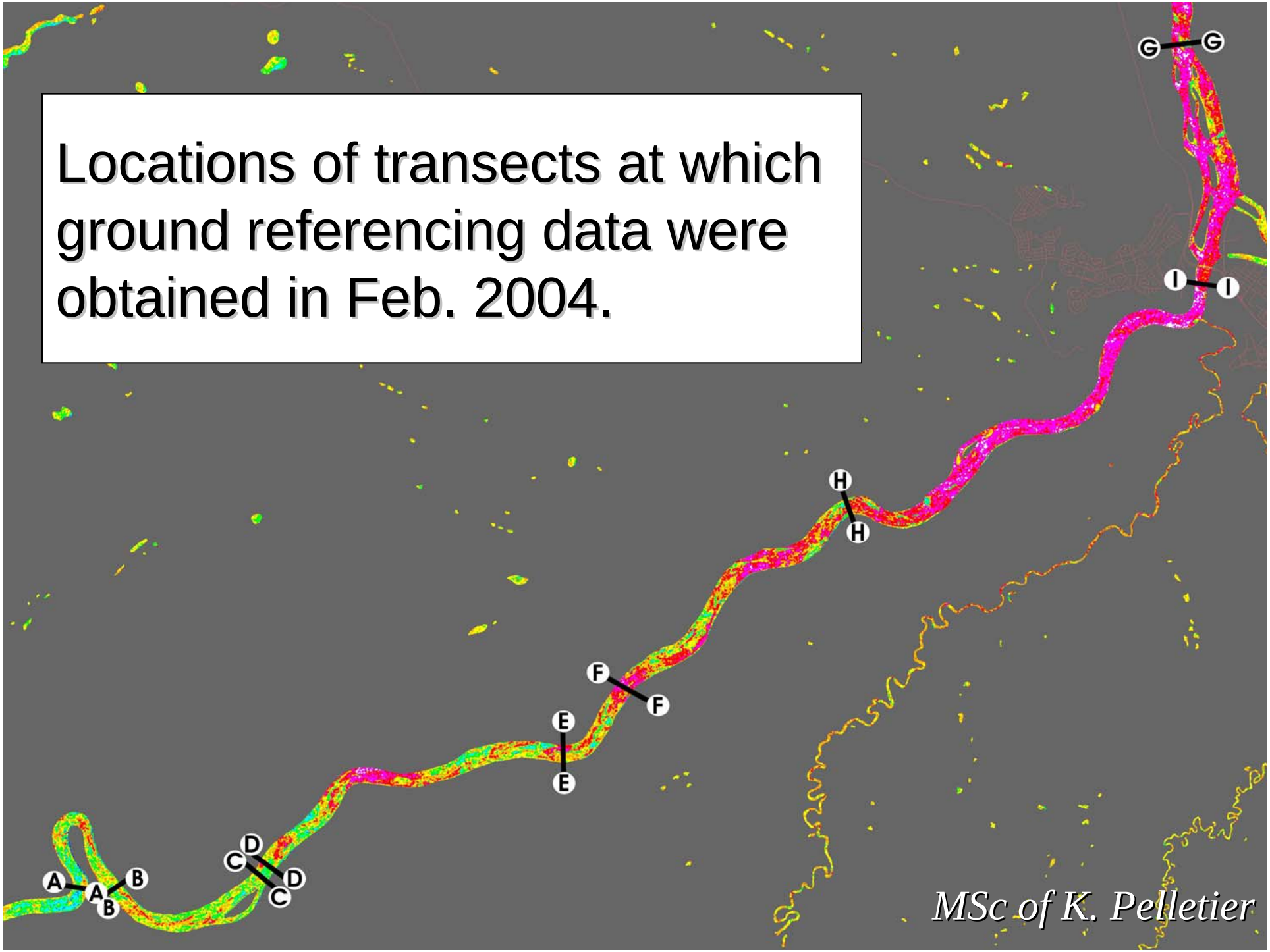
These items must be of adequate size relative to the radar wavelength to affect radar return.

UofA/CCRS research to date

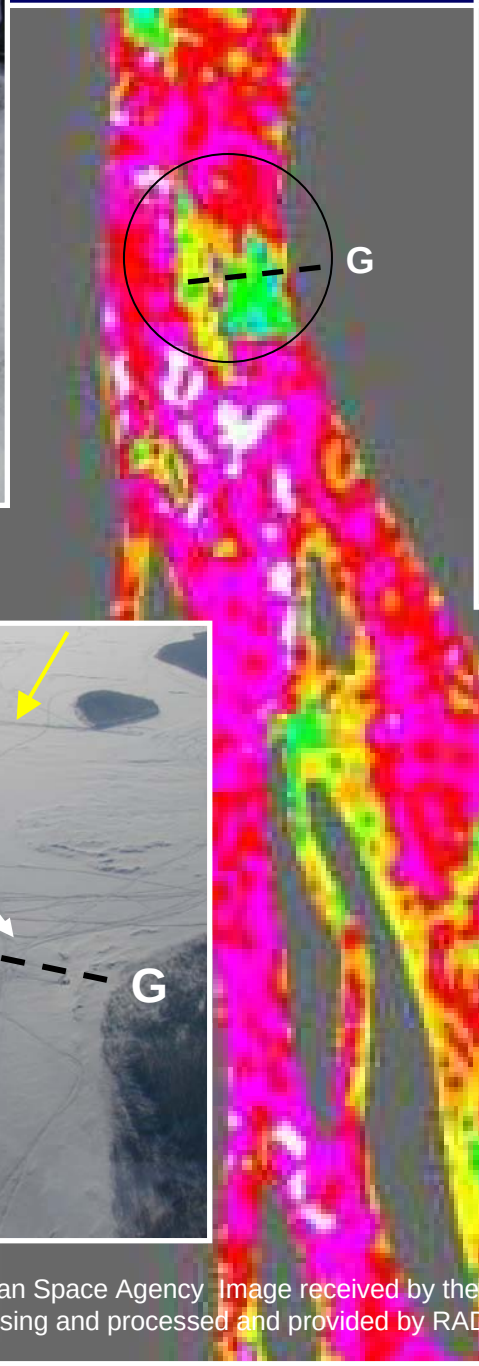
Images of the study reach have been obtained and analyzed during three major periods:

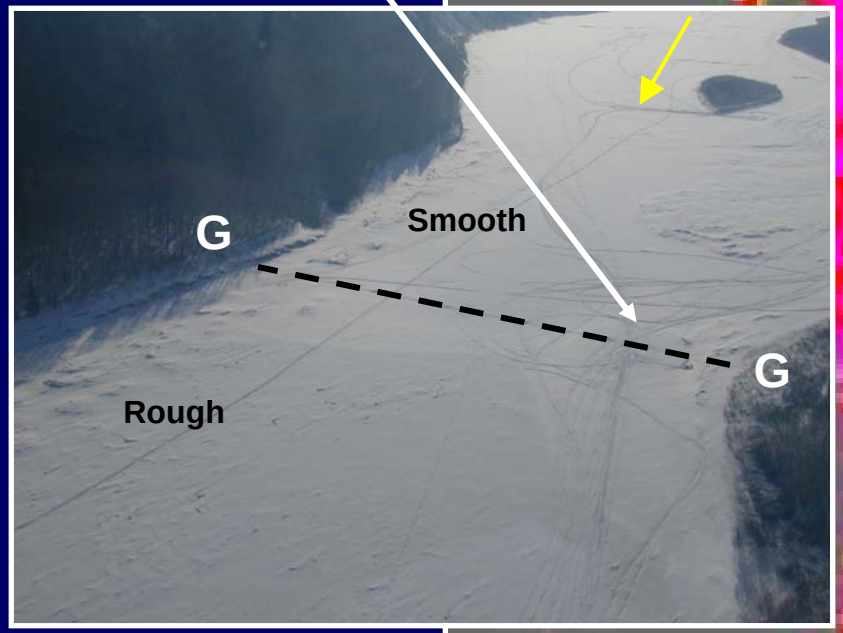
1. Mid-winter
2. Early breakup period
3. Late breakup period

MSc of K. Pelletier


Locations of transects at which ground referencing data were obtained in Feb. 2004.
A
A
B
B
C
C
D
D
E
E
F
F
H
H
G
G
I
I
MSc of K. Pelletier

Feb. 2004:
Ice thickness, composition and surface texture were documented.

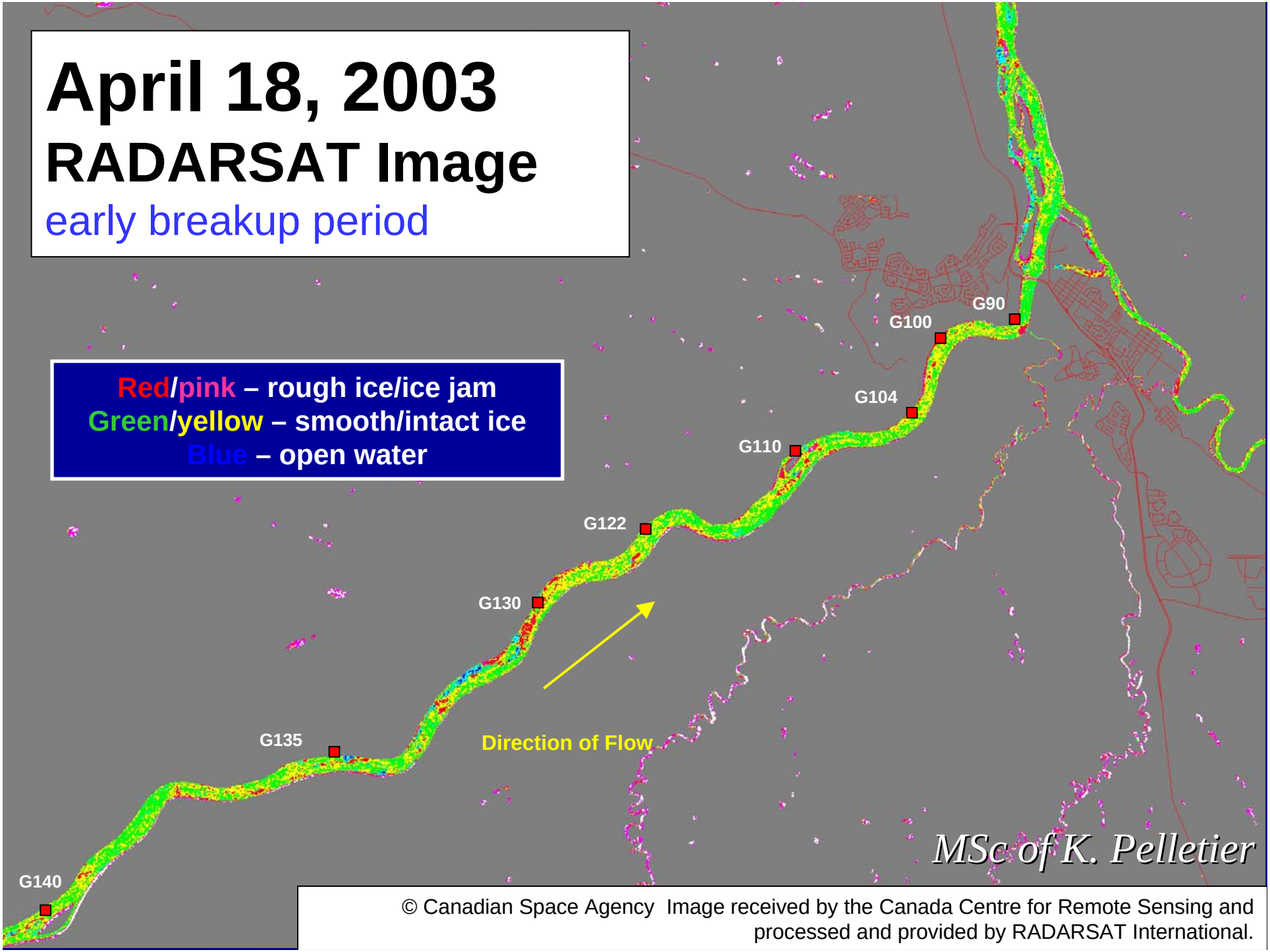




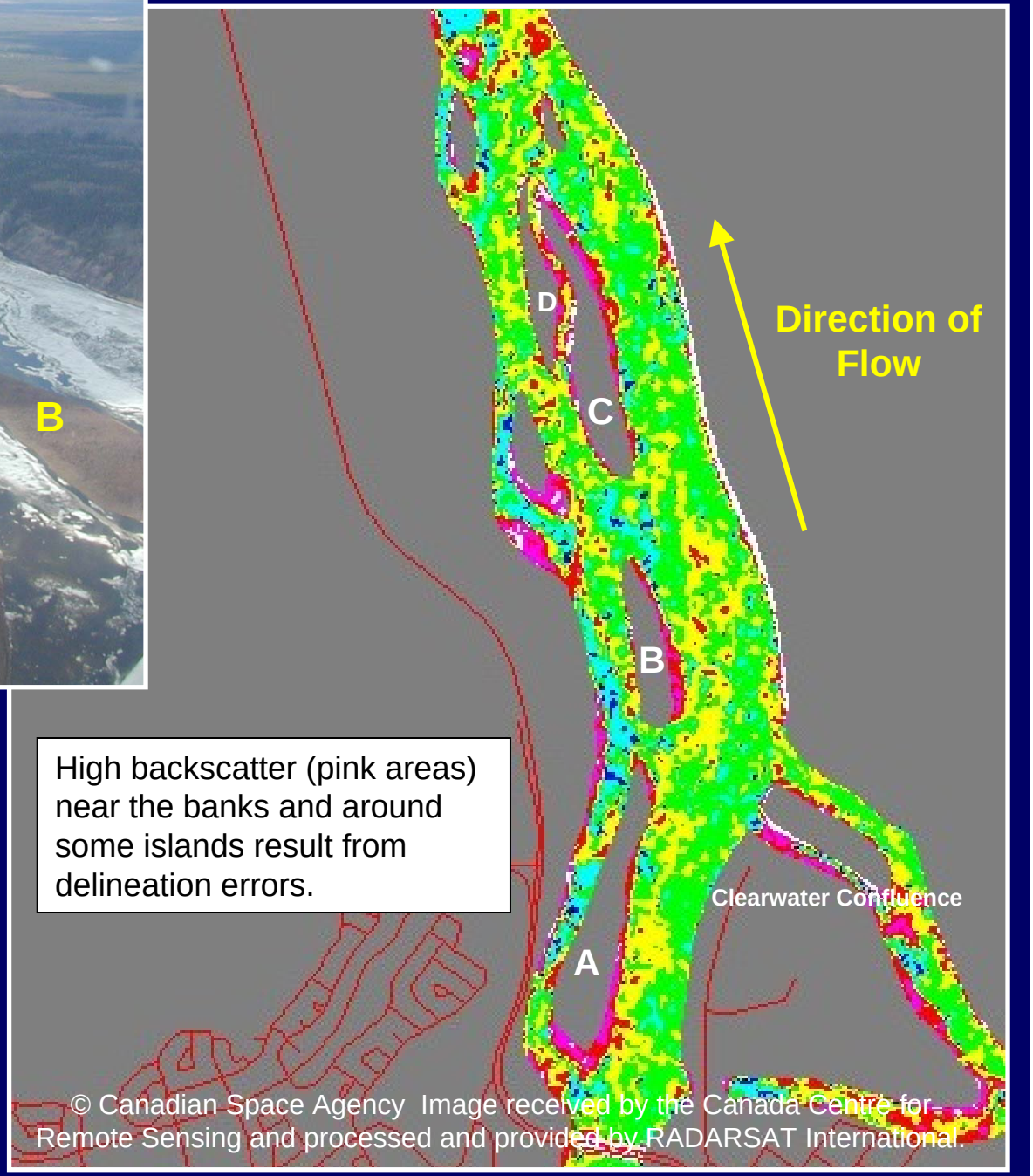
This area of lower backscatter (green) was quite smooth relative to surrounding ice (pink/red).

Very rough ice produces high backscatter (shown in bright pink/white)

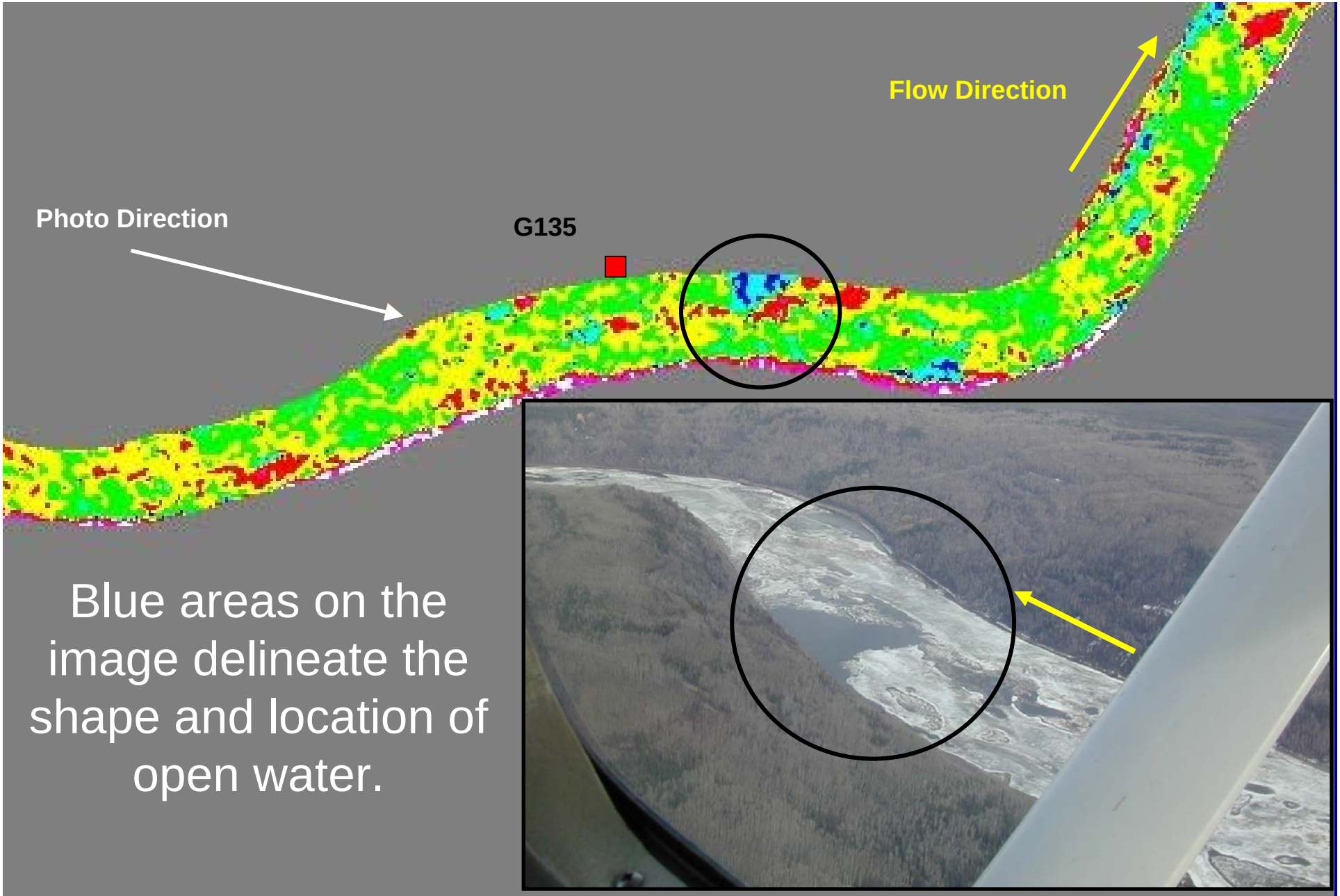
Ice that is relatively smooth produces an intermediate radar return (shown in green)



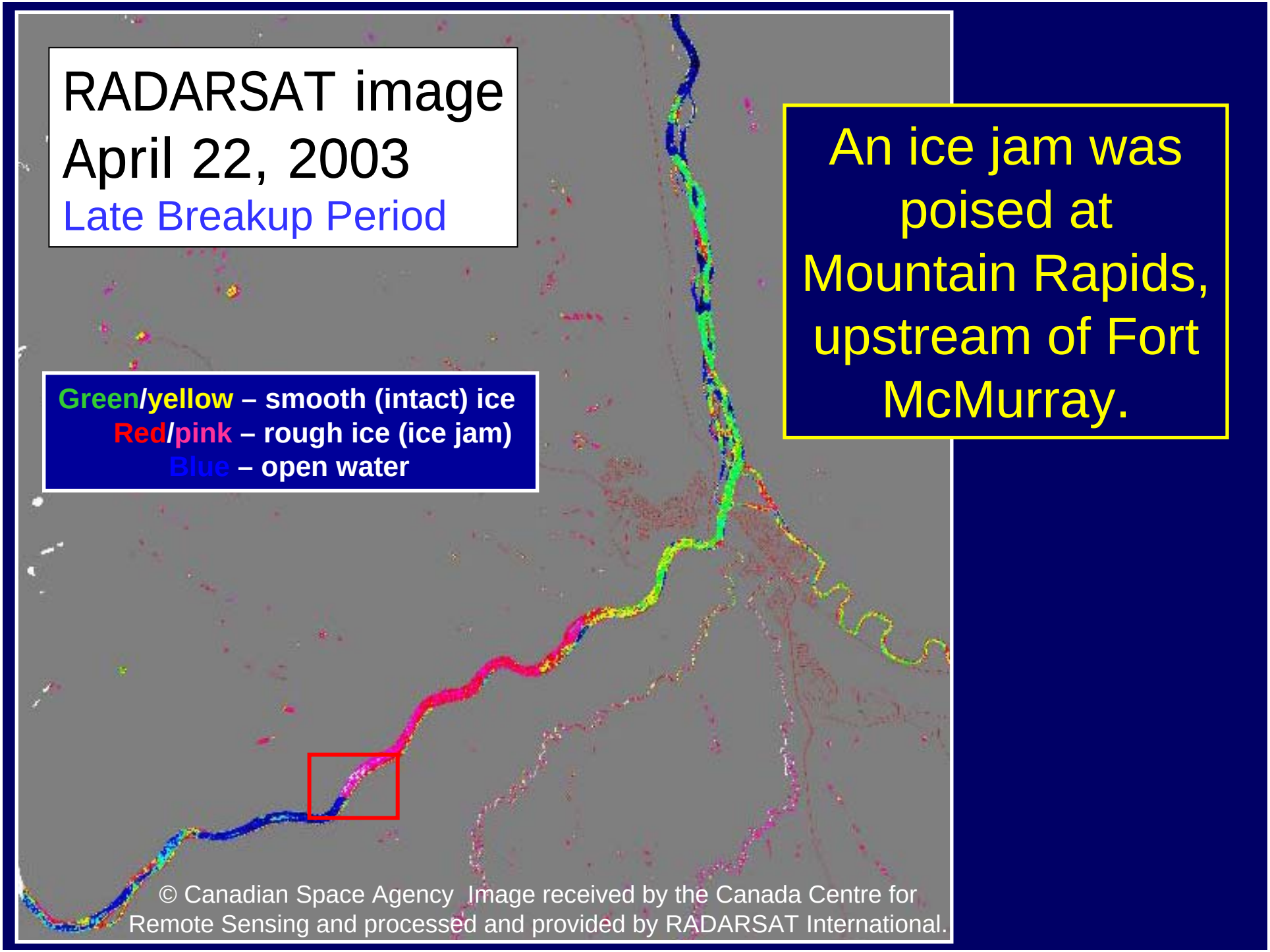
Areas of open water along the left bank (light and dark blue) can be noted in the small side channels adjacent to islands.



High backscatter (pink areas) near the banks and around some islands result from delineation errors.



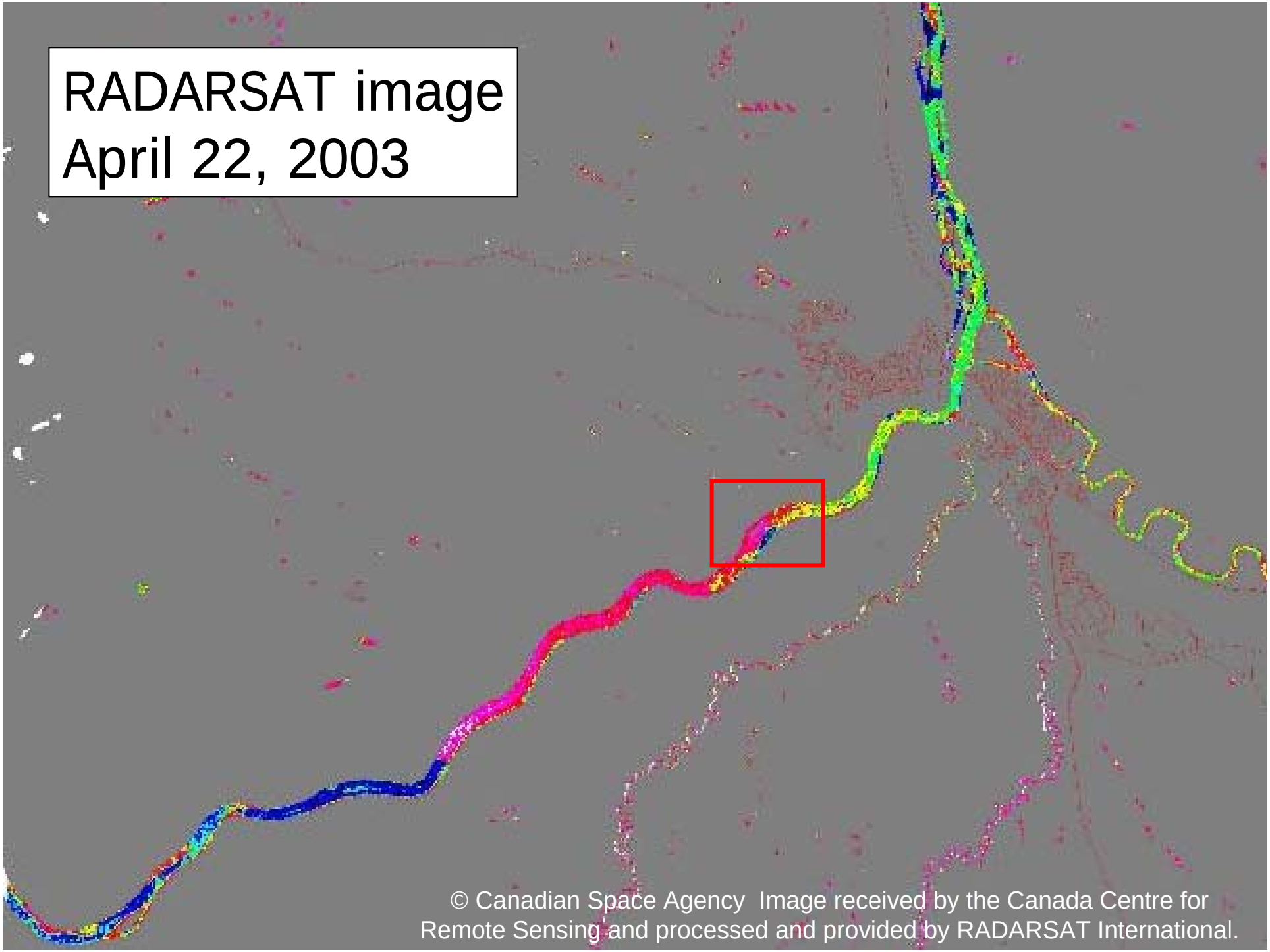
Blue areas on the image delineate the shape and location of open water.


RADARSAT image
April 22, 2003
Late Breakup Period
Green/yellow – smooth (intact) ice
Red/pink – rough ice (ice jam)
Blue – open water
An ice jam was poised at Mountain Rapids, upstream of Fort McMurray.
© Canadian Space Agency Image received by the Canada Centre for Remote Sensing and processed and provided by RADARSAT International.

G130

Flow Direction

The head of the ice jam is clearly delineated on the RADAR image.


RADARSAT image
April 22, 2003
© Canadian Space Agency Image received by the Canada Centre for
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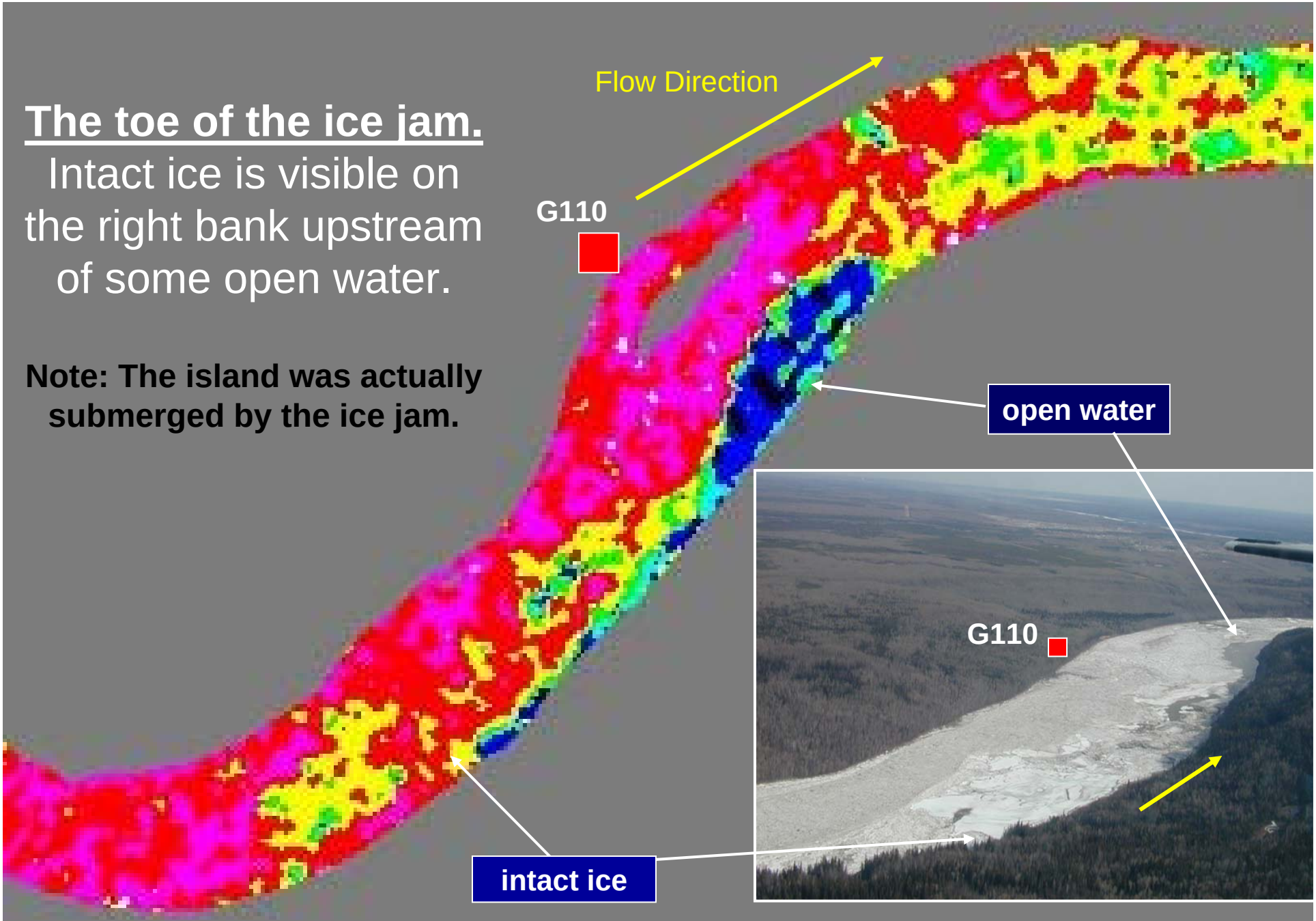
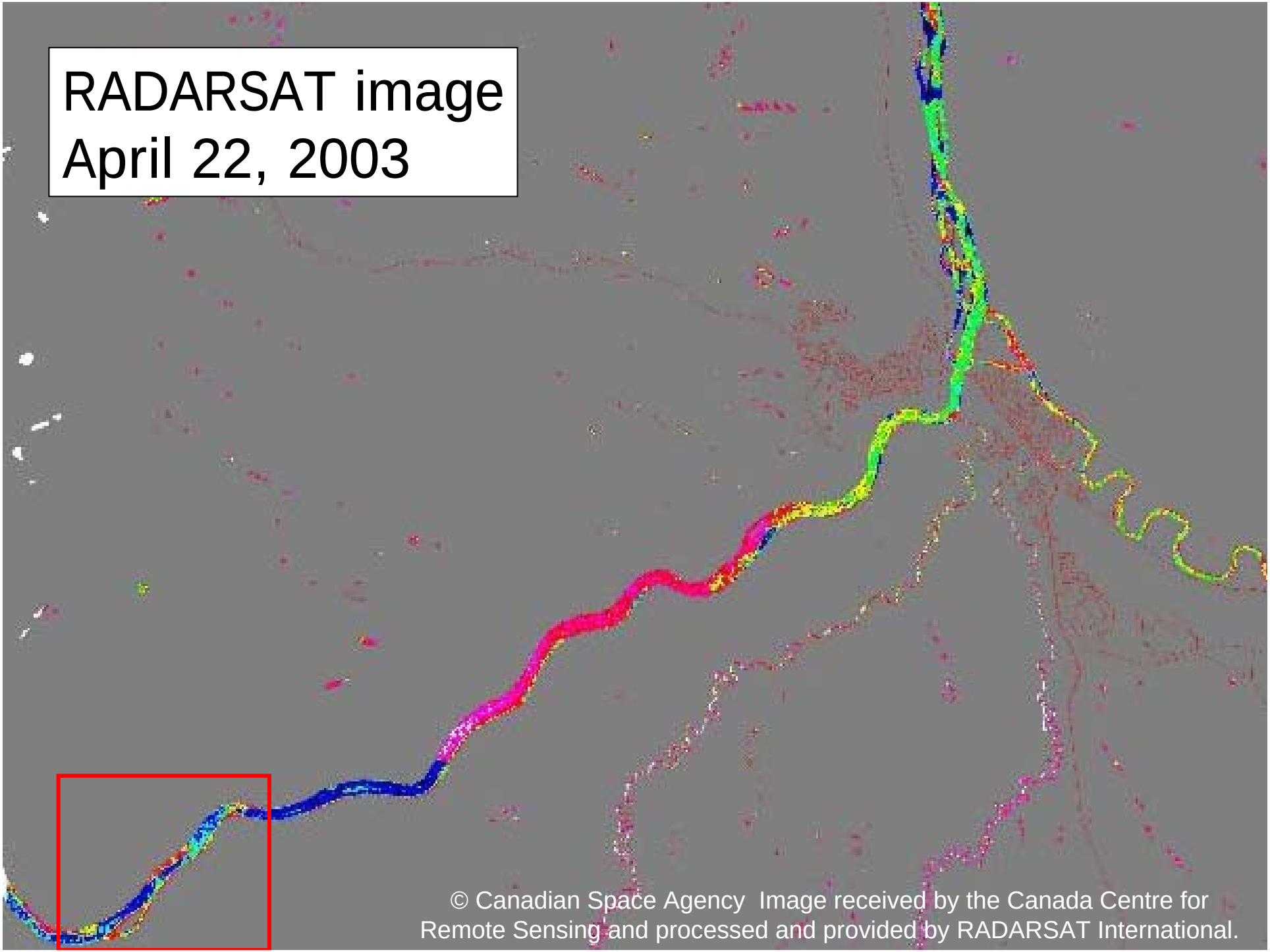
<u>The toe of the ice jam.</u>

Intact ice is visible on the right bank upstream of some open water.

Note: The island was actually submerged by the ice jam.




RADARSAT image
April 22, 2003
© Canadian Space Agency Image received by the Canada Centre for
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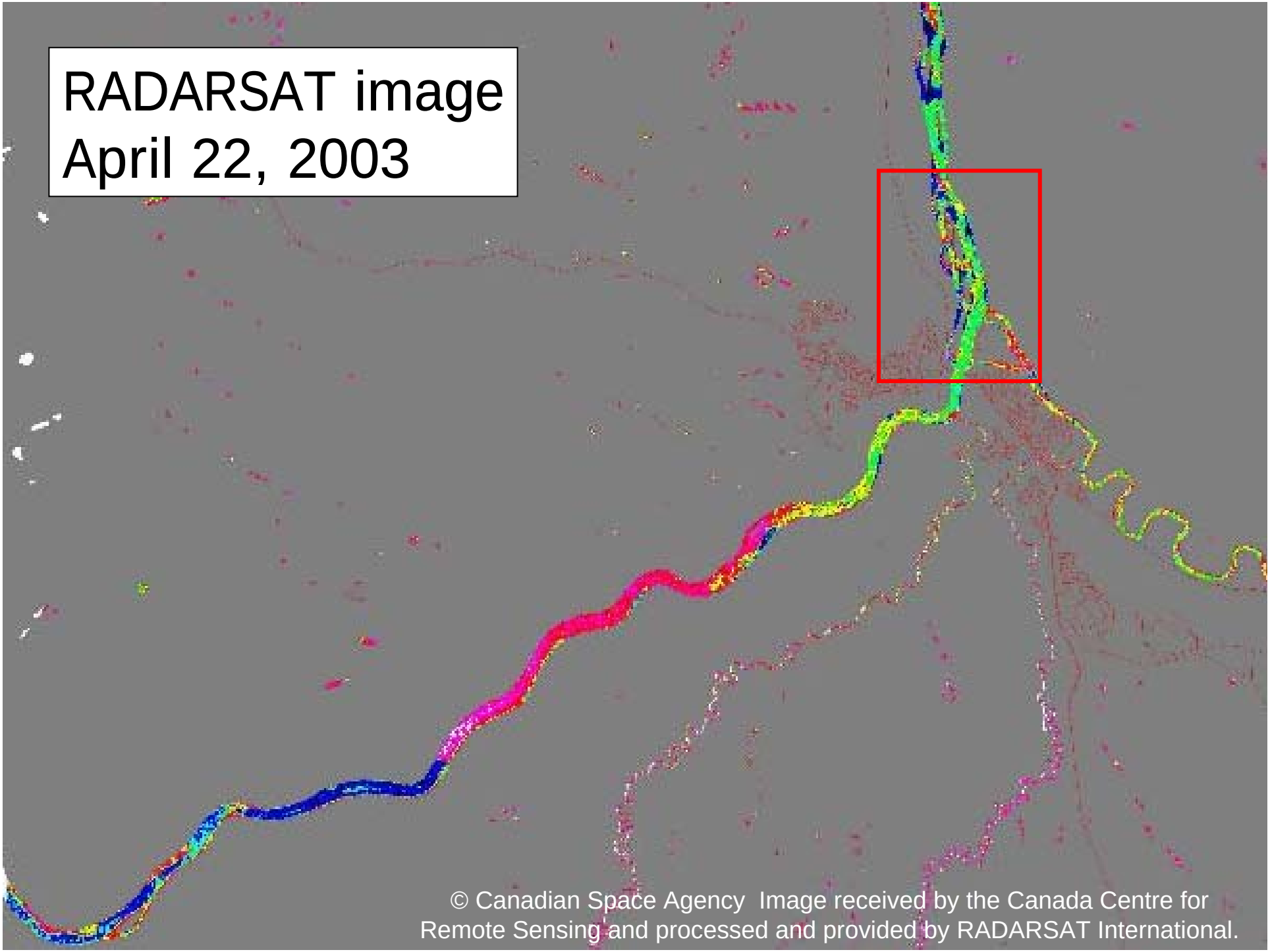
Cascade Rapids

Flow Direction

Remnant ice is visible at Station G140 and at Cascade Rapids.

G140


RADARSAT image
April 22, 2003
© Canadian Space Agency Image received by the Canada Centre for
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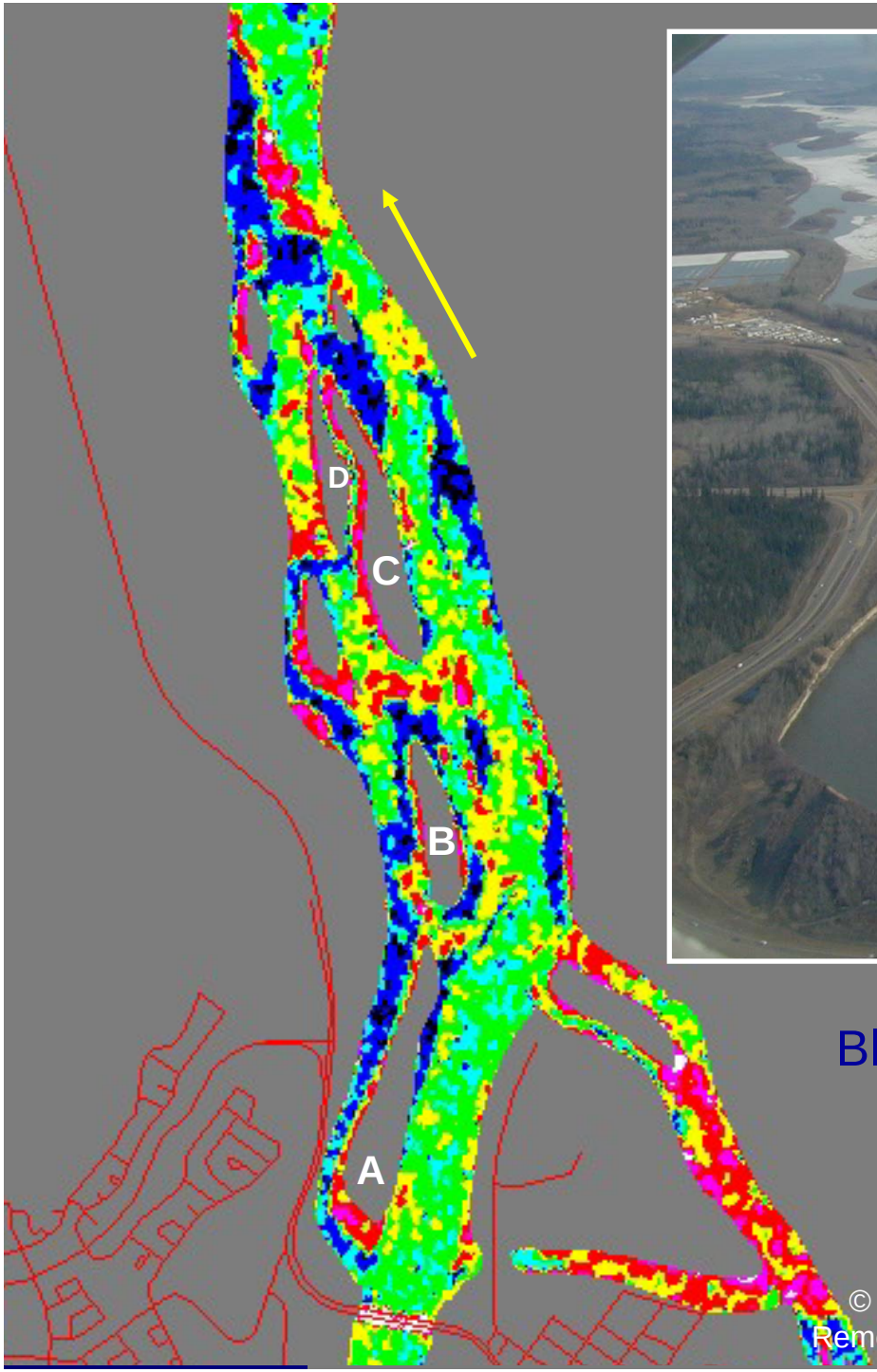
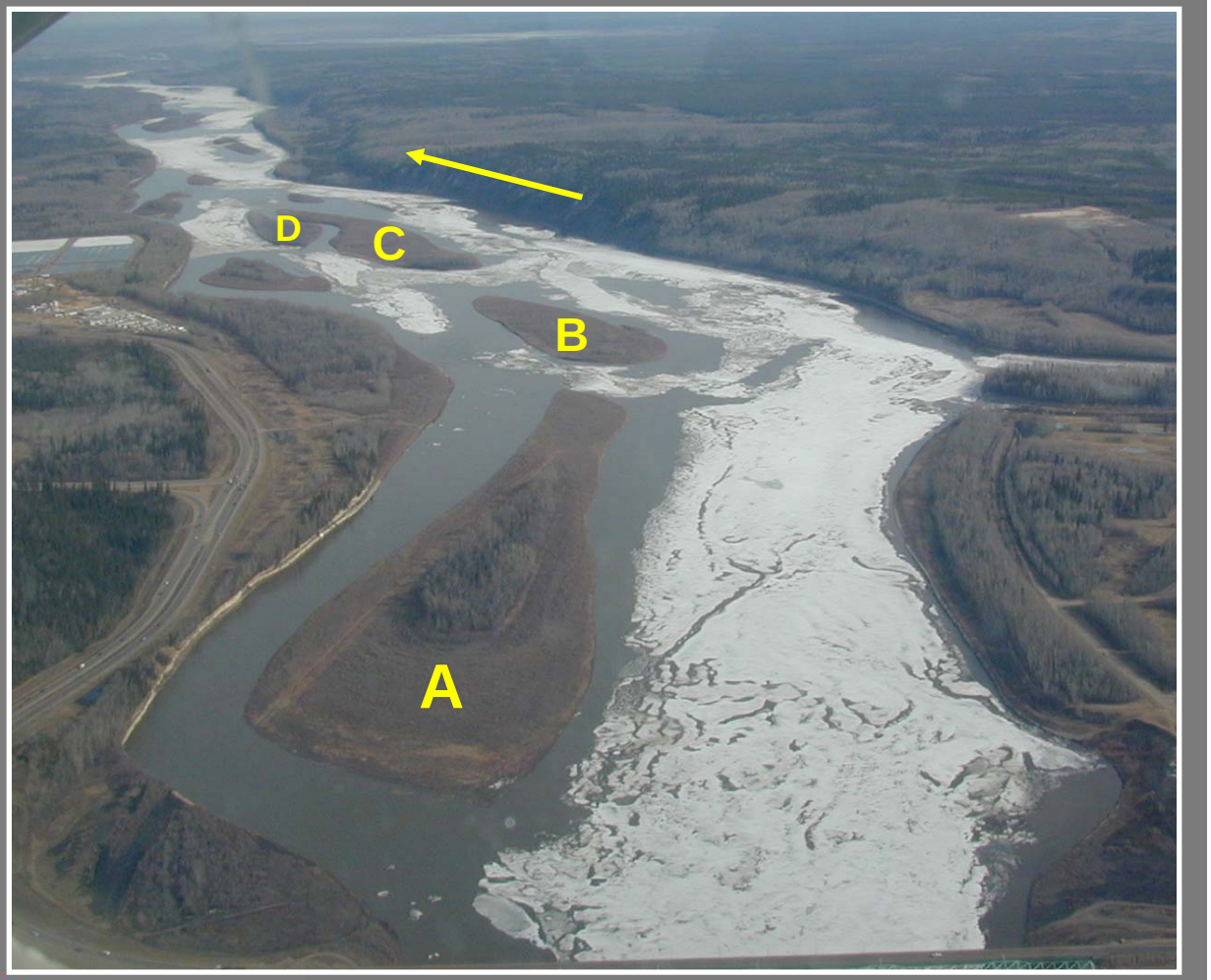
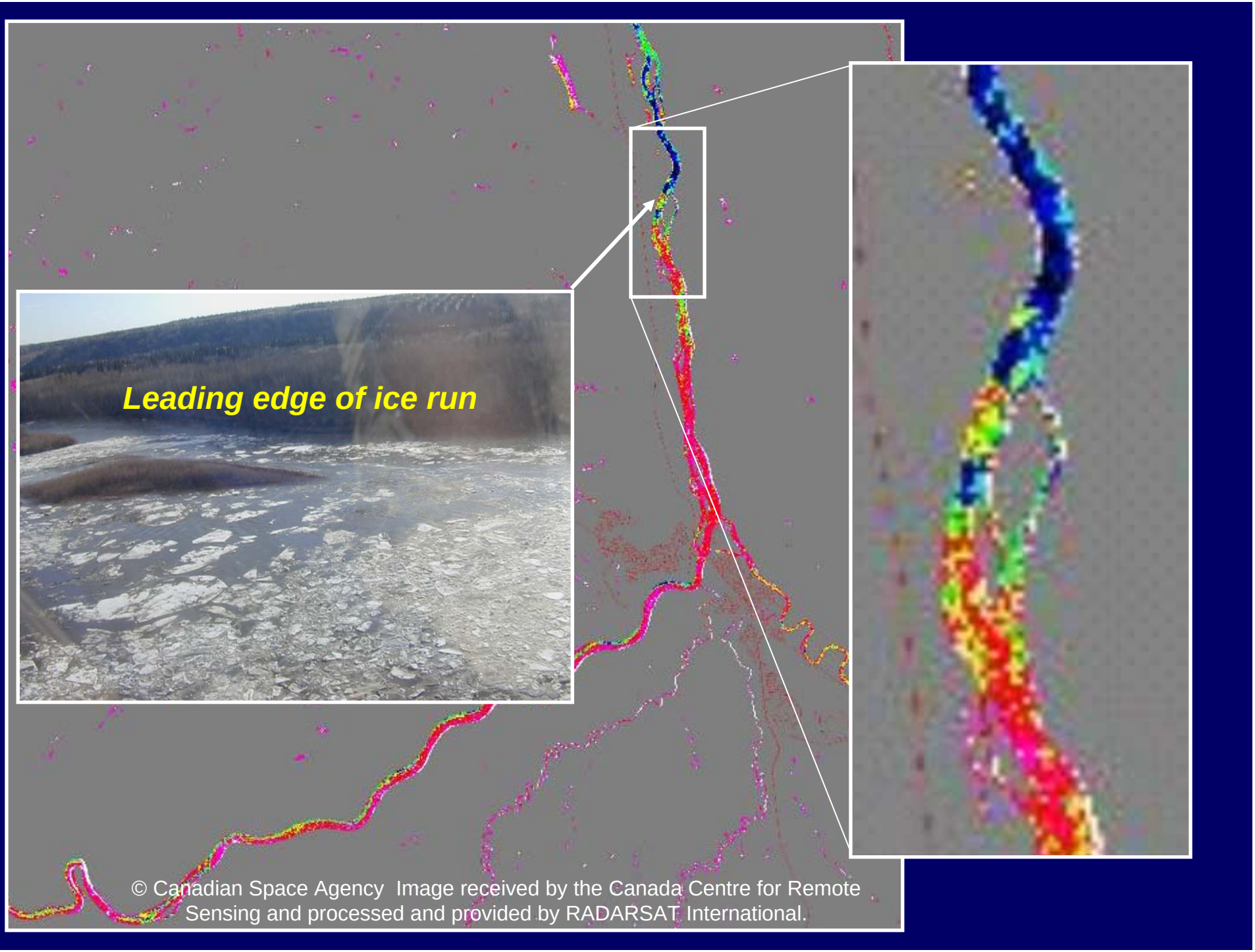




Blue areas on the satellite image clearly show the open water development downstream of Fort McMurray.

RADARSAT image
April 22, 2003

MSc of K. Pelletier



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Ice Jam Flood Forecasting Strategy

A variety of model types are needed:

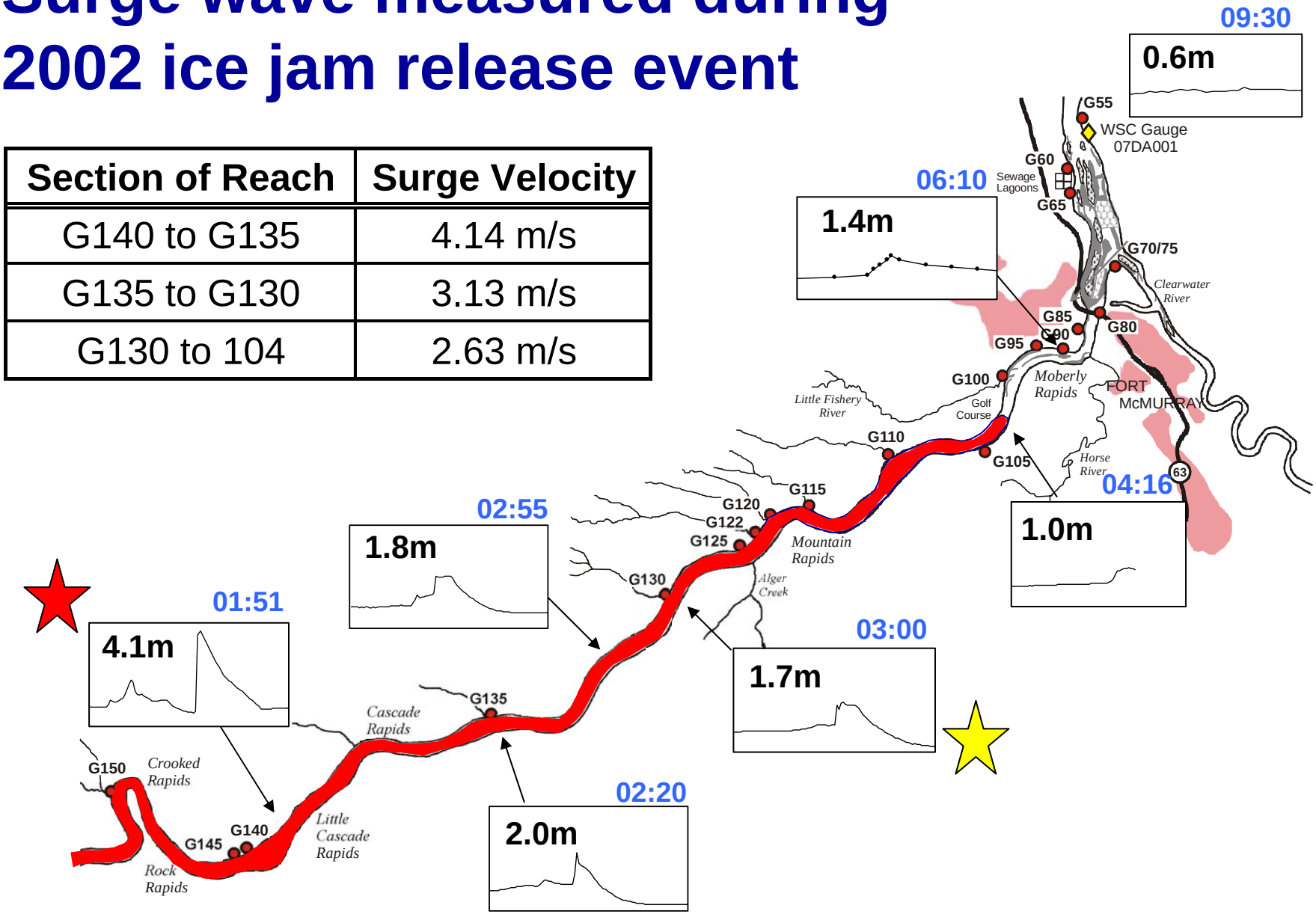
1. Long lead time forecasts (3-6 weeks)
   - qualitative indication of potential severity

2. Short lead time forecast (3-5 days)
   - reasonable estimate of potential flood level

3. Real-time forecasts (within hours)
   - accurate prediction of expected flood level and time of occurrence

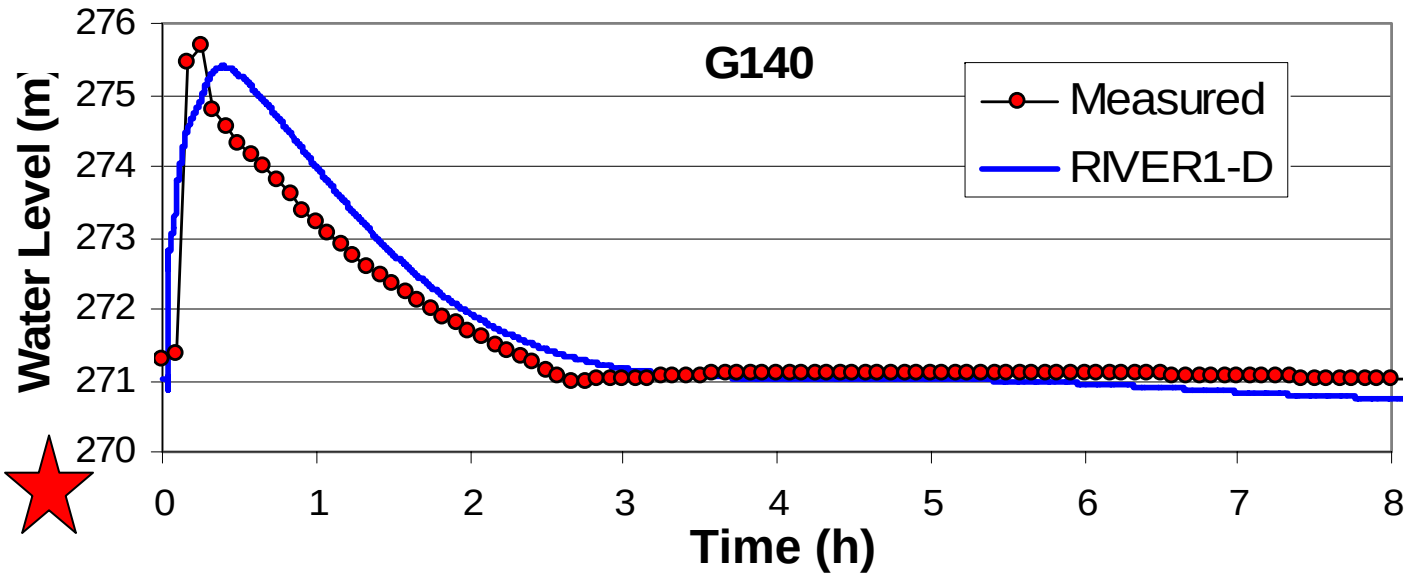
Surge wave measured during 2002 ice jam release event

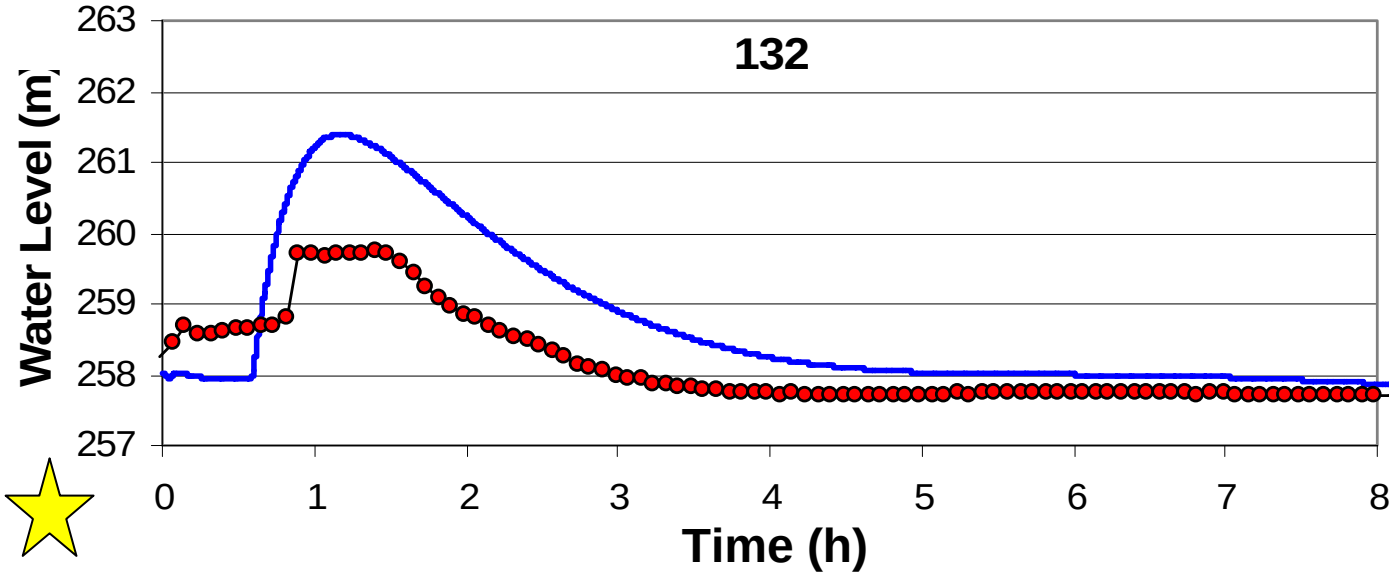
Section of Reach	Surge Velocity
G140 to G135	4.14 m/s
G135 to G130	3.13 m/s
G130 to 104	2.63 m/s



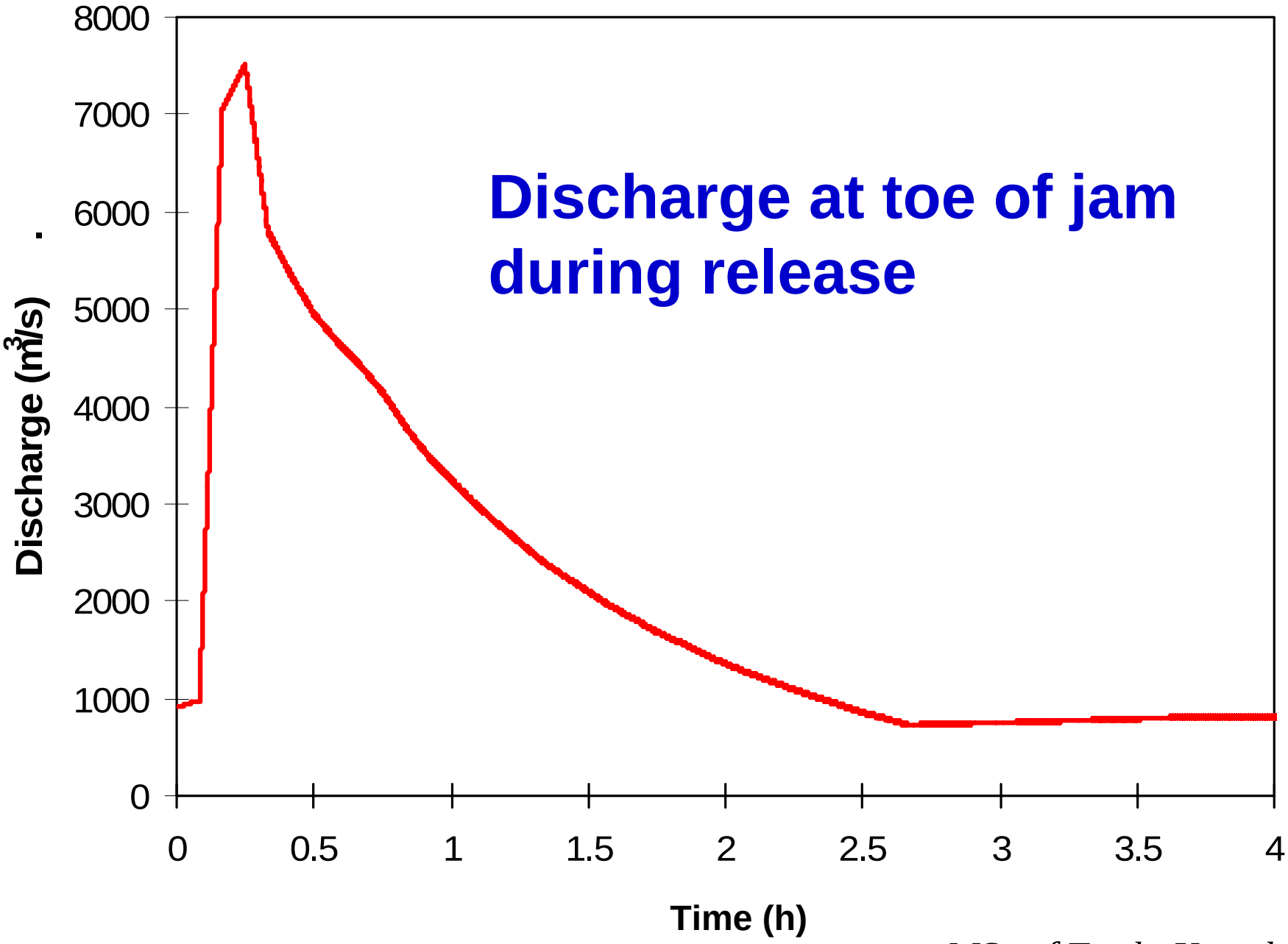
M.Sc. of T. Kowlaczyk

River1D model results (no ice effects)

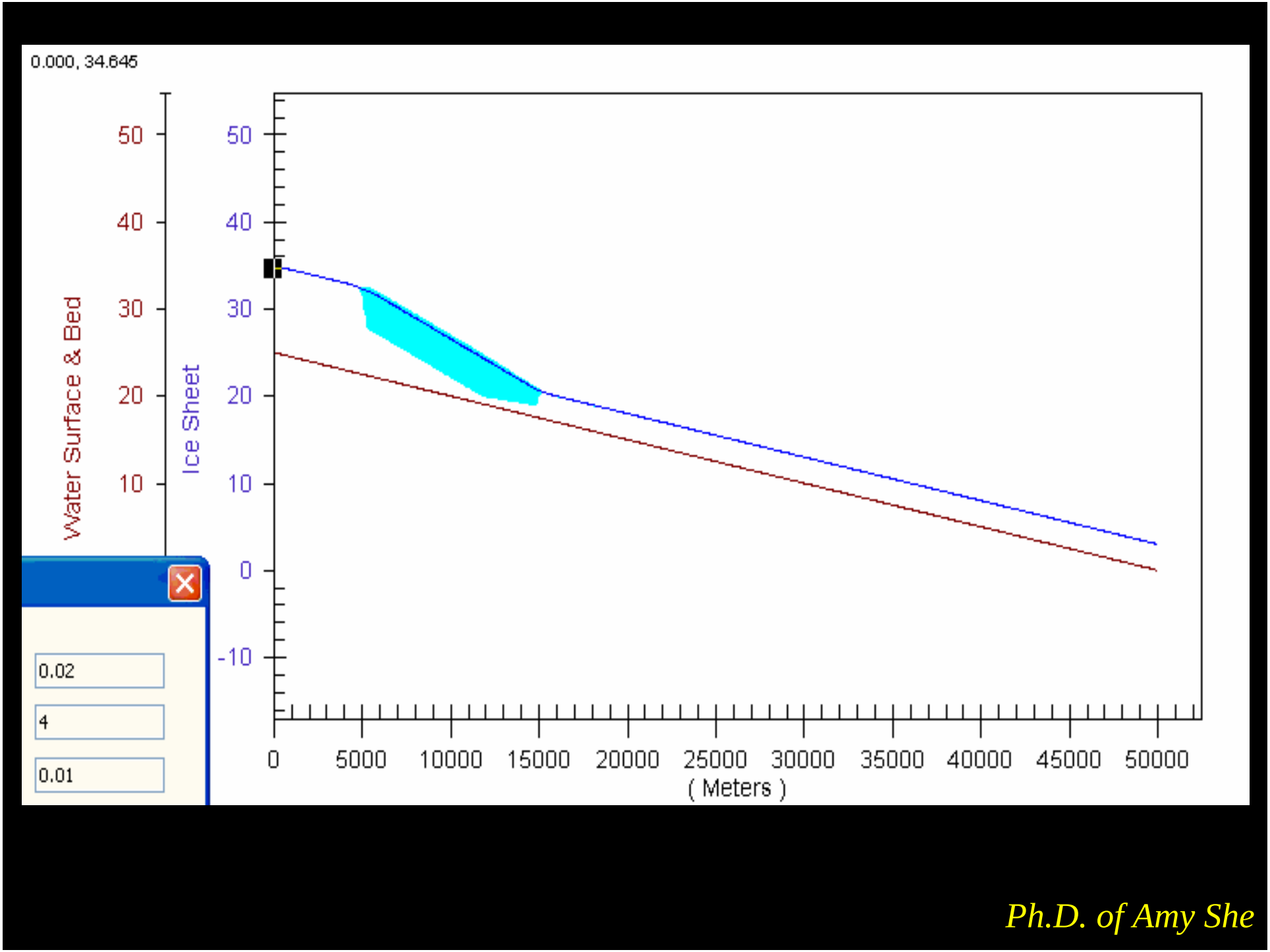




MSc of Twyla Kowalczyk



MSc of Twyla Kowalczyk



Ph.D. of Amy She


All done!
www.riverice.ca

Thank-you!

…and thanks also to the following groups and agencies for their support of these projects:

Canada's Natural Science and Engineering Research Council

Mackenzie GEWEX Study

Alberta Environment

Canada Centre for Remote Sensing/Natural Resources Canada

Environment Canada

Canada Space Agency

RADARSAT International

Regional Municipality of Wood Buffalo

University of Alberta